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METALLURGIA

THE BRITISH JOURNAL OF METALS

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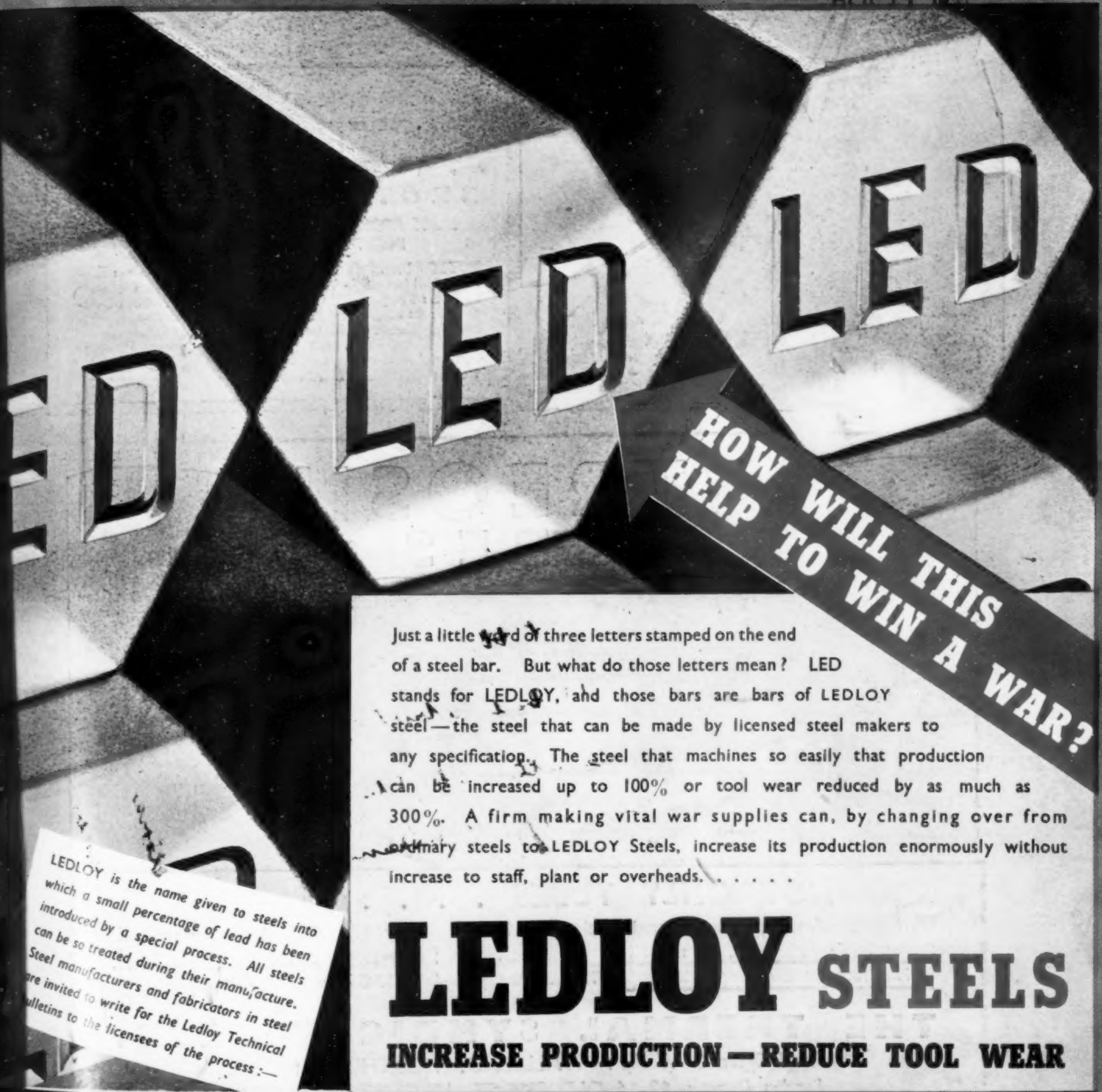

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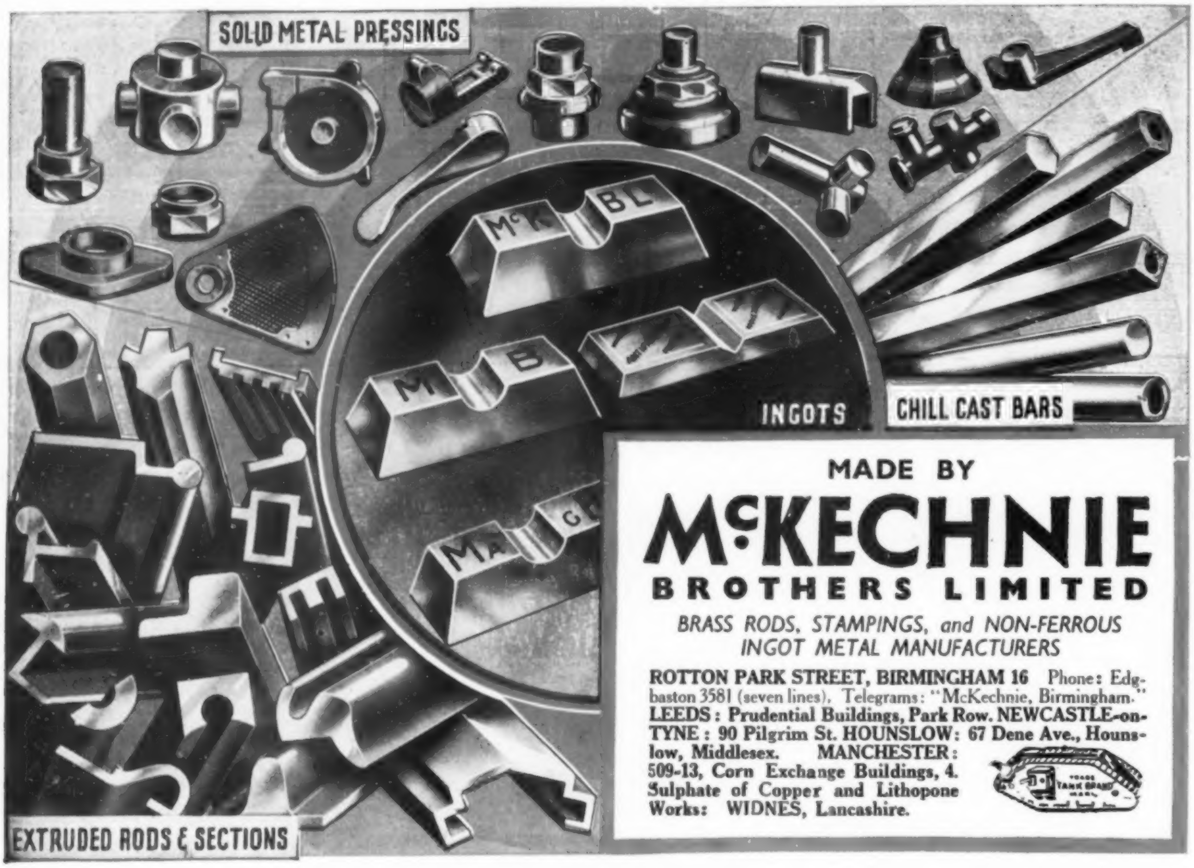

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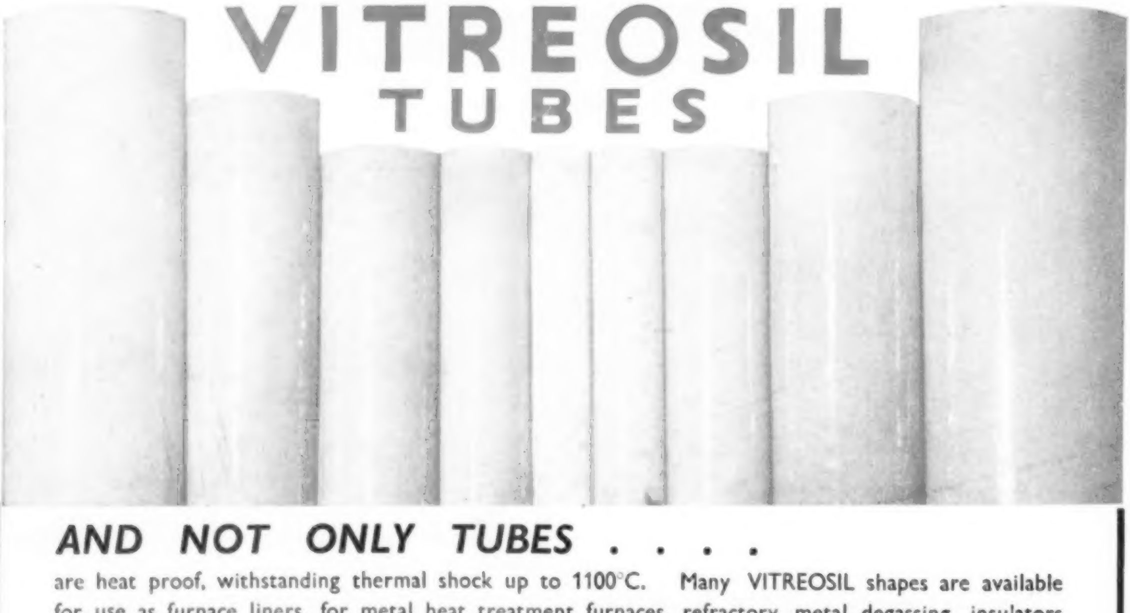

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METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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METALLURGIA

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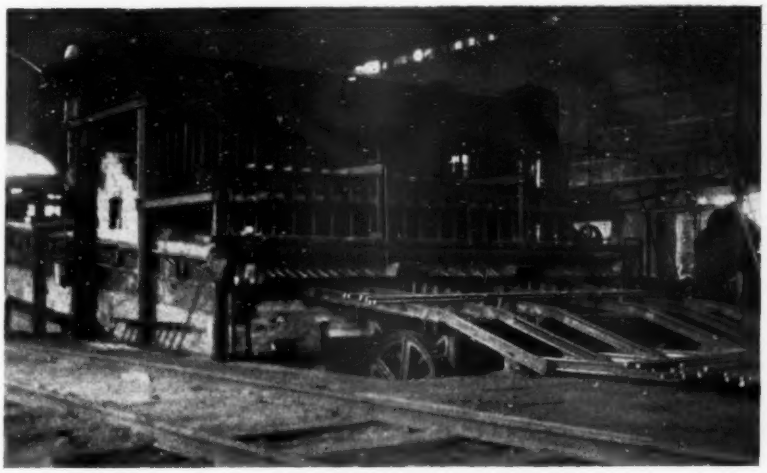
JUNE, 1940. VOL. XXII, No. 128.

A Large Furnace for Normalising Round Bars

Normalising operations are carried out for a variety of reasons in practice; they are especially important in promoting refinement and uniformity of structure in hot-rolled steel. Uniformity of time and method of heating, and rate of heating and cooling are important factors in these operations and in this article a large furnace, recently installed for normalising round bars, is briefly described.



The discharge end of the large normalising furnace designed to treat 60 tons of round bars per 24 hours.

In the conversion of steel into bars of various sizes the work of rolling and the temperature at which the work is performed influence the structure and properties of the steel; a low finishing temperature, for instance, increases the strength of the steel but lowers its ductility, and, in order to restore ductility and promote more uniform properties, the rolled bars are generally normalised. This process is different from annealing in that the steel is air-cooled from a temperature at which it is completely austenitic. The effect of normalising varies with the size of bars treated, since smaller bars cool more rapidly, but generally the treatment yields a finer pearlitic structure than is obtained by annealing.

Many factors are involved in successfully normalising steel, not the least of which are uniformity of time and method of heating and rate of heating and cooling, to produce a uniform product. The ideal conditions are not easily attained because the question of cost is also a factor, but in order to approach near to ideal conditions and at the same time effect economy in production, furnaces are specially designed to deal with a particular product, such as is the case for round bars. For the mass treatment of bars the continuous furnace comes near to the ideal condition of individual treatment; it provides a regular input and output of material and control of the factors affecting time and rate of heating, and can be adjusted to manufacturing requirements.

Such a furnace recently was designed and built by Messrs. King, Taudevin and Gregson Ltd. for a well-known steelworks. Fired by producer gas, this furnace has been designed to deal with 60 tons of round bars per 24 hours, varying in size from ¾ in. to 4 in. diameter and between 12 ft. and 20 ft. in length. The bars to be normalised are placed in the charging rack at the entrance of the furnace and are fed into the furnace progressively as each finger on the conveying mechanism arrives at skid level.

The mechanical arrangement for conveying the bars to the furnaces is very similar to other types of conveying furnaces, and comprises a cast iron chain possessing fingers of heat-resisting steel, which are fitted at intervals of 9 in. to accommodate the largest diameter bars and to allow a uniform space between them for even heating of the hearth. The driving sprockets at each end of this mechanism are of robust construction and are mounted on adjustable slide rails for tension adjustment.

An important feature in the design of this furnace is the overhead heating by means of producer gas. The hearth of the furnace is 30 ft. long and 22 ft. wide and is generally 1 ft. 6 in. high from the hearth to roof. The roof is constructed on this firm's flat arch construction principle and is shaped to accommodate the input of heat from the burner ports. The gas is conducted across the width of the furnace by means of an overhead gas main from the bottom of which the ports conduct the gas into the furnace chamber.

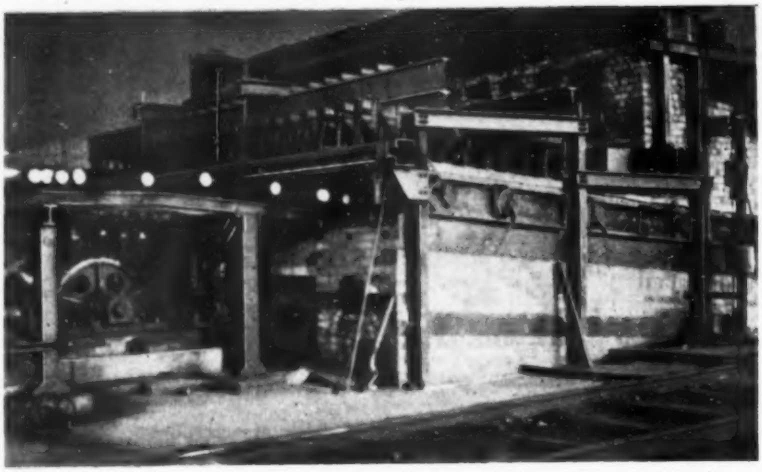
Each down-take port serves two openings into the furnace, each opening being supplied with a separate supply of pre-heated air for combustion purposes. To give even heating the gas ports are elongated with a minimum height and arranged to receive the combustion air from the top in a parallel slot. Both gas and air ports are adjustable providing even flow throughout the entire width.

The ports are arranged to project the products of combustion towards the outlet end causing the heating flame to turn around thus striking the hearth before proceeding up the furnace to the waste gas exits. This system of combustion prevents excessive radiation from the point of ignition and ensures even mixing within the area allowed. A further advantage is, delayed combustion can be effectively produced due to the turbulence caused by the change in direction.

The waste gases are taken out through ports at either end of the furnace, the larger quantity being withdrawn at the inlet end to preheat the incoming bars. The waste gases after passing from the heating chamber proceed in flues under the hearth towards the centre where they are connected to a main chimney flue. The two outer flues form the heater for the metallic recuperator.

The air for combustion is provided by a fan mounted at floor level and is conveyed to the two recuperators by tubing and by flues to the supply main running parallel to the gas main. From this supply main the air is taken in small ducts to the individual port through the controlling valve. A master control of this air is provided at the fan outlet which is adjacent to the main gas valve.

The furnace hearth slopes in a downward direction from inlet to outlet to encourage the bars to rotate rather than skid during their passage through the furnace.



The charging end of the large normalising furnace; note the mechanical conveyer collecting the bars to be transported through the furnace.

The speed of the bars through the furnace can be adjusted to ensure that the size of bars under treatment will be uniformly heated throughout; the range is between 1 ft. in 4 min. to 1 ft. in 2 min. The furnace chamber comprises different heating zones; for about half the length of travel in the furnace the bars are preheated, and are subjected to a final heating period during the next quarter of the distance of travel, the remaining quarter being allowed for cooling before discharging to the racks for cooling in air. It is noteworthy that adequate expansion doors are provided alongside the furnace to preserve the passing bars and to remove any which may foul the fingers of the conveyer.

The speed of output is under the control of variable speed V-rope drive and to absorb the shock a further chain drive is incorporated between the reduction gear and sprocket shaft. As the bars leave the furnace they pass through a self-opening door and are guided to the side of the runway skids where they discharge themselves on to a cooling rack.

This normalising furnace has been continuously applied to the treatment of round bars long enough to indicate that this method of heating, cooling and handling round bars restores the ducility of the steel and maintains a high degree of uniformity in its properties, in addition, the cost of treatment is relatively low.

A.S.T.M.—1939 Proceedings

THE Proceedings of the 1939 Annual Meeting of the American Society for Testing Materials are issued in one volume under the society's new publication scheme, by which all new tentative standards (formerly published in Proceedings) are included in the 1939 Book of Standards, thus enabling the former two volumes—Part I, Committee Reports, and Part II, Technical Papers—to be combined. This edition covers some 1,350 pages.

The reports of A.S.T.M. committees give full details of the important recommendations on specifications and standardized test methods for materials, and in many cases include important data and information in the form of appended section reports or papers. Eleven of the reports pertain to ferrous metals, including extensive reports on field tests of metallic coatings on wire and wire products. Reports on inspection of stainless steel, metallographic examination of the 18% chromium, 8% nickel alloy are given. Also included are reports on effect of temperature dealing with grain size, torsion tests, and correlations of test results. Seven of the reports are on non-ferrous metals and alloys and include extensive technical data on galvanic and electrolytic corrosion tests, proposed classification of cast copper and copper-base alloys, and a discussion of magnesium alloy die castings.

In the field of cementitious, ceramic, concrete and masonry materials there are eleven reports with several appended items dealing with cement problems, two industrial surveys of conditions surrounding refractory service (lime burning, plate-glass and window-glass furnaces). Other reports cover gypsum, concrete pipe, glass and glass products, mortars for unit masonry and manufactured masonry units.

Other reports classified under the general heading, "miscellaneous materials," pertain to paint, varnish, lacquer, and related products; petroleum products and lubricants (appended material covers gum and tetraethyl lead in gasoline and proposed specifications for aviation gasoline); and other reports covering gaseous fuels; road and paving materials; and coal and coke. Also included in this portion are contributions from technical groups in the field of paper and paper products, timber, bituminous waterproofing and roofing materials, electrical insulating materials, rubber products, soaps and other detergents, textile materials, naval stores, soils for engineering purposes (four proposed methods appended to this report) water for industrial uses, and plastics.

The section devoted to technical papers is preceded by the Fourteenth Edgar Marburg Lecture on "Stress, Strain, and Structural Damage," by Prof. H. F. Moore; there are 20 papers dealing with metals, 16 covering cement and concrete and masonry materials, eight comprising the Symposium on Shear Testing of Soils, and 15 cover miscellaneous materials and subjects. Topics covered in the papers on metals include work-brittleness test, testing block for heat-resisting alloys, mechanical properties of cast iron, contributions on radiography, and mechanical tests on aluminium alloys. In the cement and masonry group are papers covering particle size distribution, an outstanding contribution on lean concrete mixes, and several papers on other problems in the field of concrete. One paper gave important results on the thermal volume change and elasticity of aggregates. The symposium on shear testing of soils covers some 125 pages.

Other technical papers cover laboratory wet-gas meters, tests of rubber and rubber-like materials, five items on industrial waters—particularly boiler-feed water, two papers on Rockwell Hardness, and a study of the influence of speed on the torsion impact test.

Copies of the 1939 *Proceedings* can be purchased from the A.S.T.M. Headquarters, 260 S., Broad Street, Philadepia, Pa., at $8.50, heavy paper binding; $9.00, cloth; $10 half-leather.

The Use of Refrigeration for Delaying the Age-Hardening of Duralumin-type Alloys, with Special Reference to the Production of Large Pressings for Aircraft

By J. C. Arrowsmith, M.Sc. and K. J. B. Wolfe, M.Sc.

The age-hardening of Duralumin after solution treatment results in a pronounced reduction of ductility in the early stages, which seriously interferes with cold-pressing operations. The rate of age-hardening can be retarded by lowering the temperature of storage of the freshly-normalised material; in a paper the authors describe experiments carried out to demonstrate the relationship between temperature of storage and rate of age-hardening. Reference is made to a suitable form of refrigerated store and its practical advantages, when used in conjunction with a heat-treatment department, are discussed. The practical application of the results of the experiments are given.*

THE improvement in the physical properties of Duralumin-type alloys, which have been subjected to the normalising solution treatment, normally takes place at room temperature over a period of about four days, but a decrease in ductility, which becomes apparent within an hour or so of treatment, constitutes a definite hindrance to its fabrication. Any operation involving bending or stretching must be carried out within a comparatively short time of solution treatment, otherwise the material must be again solution treated to restore its ductility. As soon as the number of pieces involved increased to the point where reheat-treatment became a hindrance, attempts were made to discover a remedy, and the first instance of these was the use of refrigerators for storing Duralumin rivets.

The knowledge that age-hardening could be retarded and the necessary degree of ductility retained by storing the solution treated material at low temperature has long been available, but there has been a lack of detailed information on the subject. During the last few years, however, developments have taken place which have made it essential to reconsider the possibilities of the low-temperature storage of Duralumin after solution treatment. Increased aircraft production has necessitated the production of die-pressed panels along lines similar to those adopted for the mass production of motor-car body parts.

In order to facilitate production it was decided to investigate the possibilities of storing the heat-treated blanks at sub-normal temperatures, the main object being to determine the maximum temperature at which a desired, but not necessarily maximum, increase in permissible storage time could be obtained. Three sheets of Duralumin to B.S.S. 4L3 were used in the tests, and their chemical analyses are given in Table I.

The initial treatment of all the test-pieces was the same—viz., heating for a suitable time (20 mins. in the case of the 20-gauge material, and 40 mins. in the case of the 14-gauge sheet) in a bath of molten sodium nitrate at a temperature of 490° ± 10° C. followed by rapid transference to, and quenching in, running water at 15° C. The test-pieces were then immediately transferred to a refrigerator operating at the temperature under investigation. The temperatures at which ageing effects were studied were: 22°, 0°, – 6°, – 11°, and – 18° C.

The results of the preliminary series of hardness tests are shown in Fig. 1, from which it will be observed that in all cases there is a certain interval immediately after the normalizing quench in which practically no change in hardness takes place. The interval is not of the same length in all samples of material, the period of delay being greater when the age-hardening temperature is lowered. After the period of delay, age-hardening proceeds at a rate related to the temperature of storage, the rate decreasing considerably as the maximum degree of hardening is approached. The effect of decreasing the temperature of ageing is very pronounced, and it is found that, when the temperature has been reduced to – 11° C. the time required for age-hardening to reach the value at which it interferes with press work, has been extended to a matter of weeks.

Practical Application of the Information Obtained

From the results of the tests it was decided that a temperature in the range – 6° to – 10° C. would be the most useful and economical temperature for the storage of heat-treated blanks; the limiting ageing period would then be of the order of 100 hours, and it could be safely assumed that no appreciable age-hardening would occur in the initial 50 hours of storage. Practical confirmation of the reliability of deductions regarding the limiting ageing period, based on the experimental evidence, was obtained on a press run of aeroplane petrol-tank-end pressings. Invariably trouble was experienced with this pressing if the blanks were allowed to age-harden at room temperature for more than half-an-hour. Entirely satisfactory results were obtained on blanks stored for 24 hours at 0° C. after normalising, and others stored for 200 hours at – 18° C. were similarly trouble free.

Table I.
Compositions of Materials.

Constituents.	Sheet Identification Number.		
	1	2	3
	Thickness.		
	0·035 in.	0·035 in.	0·080 in.
Copper	4·14%	3·92%	4·02%
Manganese	0·53%	0·54%	0·51%
Magnesium	0·61%	0·49%	0·46%
Silicon	0·34%	0·42%	0/38%
Iron	0·61%	0·38%	0·45%

The details of construction of a refrigerated store for Duralumin blanks were next considered, and the first suggestion was to follow lines similar to those adopted for the storage of perishable foodstuffs. It was then realised that bright sheet metal blanks at the temperature of the water used for quenching after normalising might take some considerable time to assume the temperature of the air in a refrigerated chamber. During this time the age-hardening effects corresponding to the intermediate temperatures would be taking place, which would bring about a reduction in the limiting ageing period at the temperature of the refrigerator.

Experiments were carried out to determine the time taken

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* *Jour. Inst. Metals*, **66**, Part 5, May, 1940, pp. 149–162.

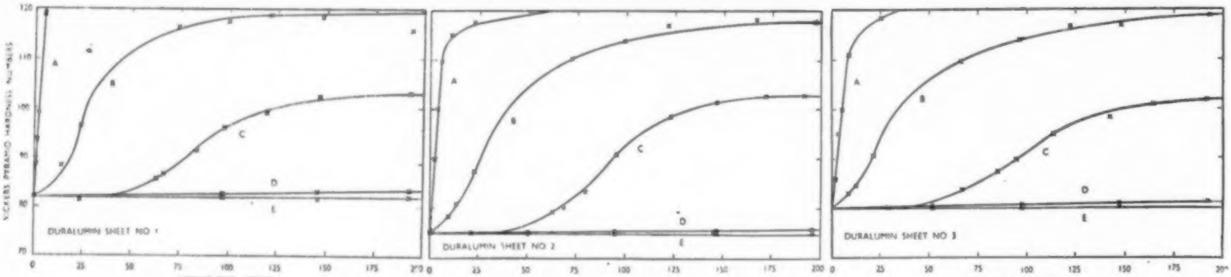

Fig. 1.—Time-hardness relationship during first 200 hours of age-hardening of three different sheets when aged at temperatures corresponding to the following key:—A—at 22° C.; B—at 0° C.; C—at −6° C.; D at −11° C.; and E at −18° C.

by blanks to cool to the air temperature in a refrigerator. Pieces of Duralumin and Alclad sheet 12 in sq. and 0·080 in. thick were used in the tests. A hole $\frac{1}{16}$ in. in diameter was drilled in the centre of each blank, and the tip of a copper Ferry thermocouple inserted. The blanks were in turn immersed in the water-quenching tank until a constant temperature was attained. They were then transferred to the refrigerator and a record of the time taken for the blanks to assume the temperature of the surrounding air. The results are shown in Table II.

TABLE II.

Material	Temperature of water-quenching tank, ° C.	Temperature of refrigerator, ° C.	Time taken for blanks to assume refrigerator temperature minutes.
Duralumin (Specification 4 L3)	19	—8	7
Alclad (Specification L 38)	19	—8	13—14

It will be noted that the Alclad sheet took practically twice as long to cool as the Duralumin, a fact which is attributed to the more highly polished surface of the former.

While these cooling times may not appear to be excessive, it must be realised that they refer only to single blanks, small in size and with a free circulation of cold air around them. Under normal working conditions large numbers of blanks would be stored in close proximity. The load on the refrigerator would be much higher and there would not necessarily be free circulation of air between the blanks. In view of this, it was decided to incorporate inside the refrigerator a liquid quench bath† held at the same temperature as, or slightly lower than, the air temperature of the refrigerator. The freshly-normalized blanks would be immediately immersed in this tank, where they would practically instantaneously be chilled to the temperature of the surrounding liquid, after which they would be removed and placed in storage racks in the main body of the refrigerator.

The liquid to be used in this bath was given careful consideration, and it was obvious that there was a fairly wide choice. Paraffin was finally decided upon on account of low cost and the fact that the film remaining on the blanks helped to spread the lubricant used in the subsequent pressing operation. Where the presence of paraffin might be undesirable, as, for example, in the case of rivets for an assembly requiring a painting operation, industrial methylated spirit or white spirit may be substituted.

A refrigerator incorporating the above refinements has been installed in the aircraft department of the works with which the authors are associated. It is erected immediately outside the saltbath shop, so as to avoid any delay between the rinsing of the blanks following the normalizing operation, and low-temperature storage. Rapid transfer to the refrigerator, together with the quench into refrigerated paraffin, are both important factors in obtaining the maximum delay in age-hardening.

The authors have also collaborated in the design of a number of refrigerated rooms, to meet the special requirements of the manufacturers using them, and all incorporating the above-mentioned quench-bath system. The same system has also been used in the design of portable refrigerated cabinets for the storage of rivets and small parts.

Conclusions

Sufficient experience has now been obtained with the above refrigerator to confirm the following points:

1. By storage in a refrigerator operating at a temperature of − 6° to − 10° C. (15°–20° F.), normalised Duralumin sheet blanks may be kept for periods up to four days without age-hardening taking place to such an extent as to interfere with cold-pressing operations.
2. The use of such a refrigerator in conjunction with the heat-treatment department materially increases press efficiency by eliminating the delays which otherwise occur when waiting for freshly heat-treated blanks.
3. The output of the heat-treatment department has been increased by the more regular flow of work, and the fact that heat-treatment of blanks can proceed regardless of the fluctuating demand from the press-shop. Fewer heat-treatment furnaces are required when a refrigerated store is available.
4. The amount of scrap due to cracked or split pressings has been reduced. This may be due to improved pressing properties resulting from reduction of age-hardening or to the better press operation brought about by reduction in interruption.

Improving the Running Properties of Light-Metal Pistons

THE running properties of lead-plated aluminium pistons are discussed by Nitzsche* and are compared with tin-plated, anodised and untreated pistons. It is reported that film thickness of lead can easily be controlled by the use of the Perner process, and that deposits as thick as 0·020 mm. are uniform in thickness. This process consists in producing a deposit by chemical reaction between the immersed aluminium piston and the metal ions in the bath, the reaction taking place at 20° C.

Tinned, leaded, anodized and bare pistons were tested in cold-starting tests where the cooling water was at −15° C. and the oil at −11° C. After the start the motor was immediately braked while running with full load at 2,000 r.p.m. The starting test lasted 2 min., in which time the coolant was warmed to 60° C. The cold-starting tests were repeated at intervals at three hours. After twelve starts the untreated pistons were scored or had seized. The lead-coated pistons stood up the best followed by the anodized and tinned pistons.

Actual service tests consisting of driving a car equipped with lead- and tin-plated pistons for 625 miles indicated the superiority of the lead-plated pistons in that damage to the film was less. Production experience with the tin-coating process shows that 1 kg. of sodium stannate is needed for 100 pistons. In the Perner lead bath 1 kg. of a complex Pb salt (50% Pb) is needed for every 100 pistons.

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† British Patent No. 14903/39.

* *Metallwirtschaft*, **18**, Oct. 20, 1939, pp. 848-851.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
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The Wider Use of Cast Iron

UNTIL recent years the iron foundry industry has suffered greatly through the replacement of cast iron by other materials. This was largely due to the rapid development of welding by which parts, previously produced as castings, could be built in mild steel from plates and sections ; but developments with other materials, and probably the lack of proper organisation of the foundry industry, were also responsible for these replacements. In recent years, however, a considerable change has been effected. A new spirit has been developed and gradually the uses of cast iron are being extended, and this progress is being accelerated by war conditions. This has become possible as a result of the spirit of cohesion now in evidence in the industry, showing itself partly through the steady growth of institutions, and partly on account of the intensive research and development work during the last 20 years. It is through these channels that improvements have been effected, in order to meet the higher standards which modern conditions demand.

The iron-founding industry is concerned, as a whole, with the wider uses of cast iron, and the paper on the subject by Mr. J. G. Pearce, director of the British Cast Iron Research Association, is very opportune. This paper was intended for the Cheltenham Conference of the Institute of British Foundrymen, which has been cancelled. The object of the paper is not so much to give a list of replacements as to provide those in the industry with an opportunity to describe new uses for cast iron since war broke out, and the degree of success or otherwise which has attended them, and to invite suggestions for further extended uses.

The preparation of suggestions for the wider uses of cast iron may be dealt with in several ways. The most wearisome and difficult would be to build up a catalogue of parts which have been or which could be produced in this material. Such a list of replacements since war broke out would assume formidable dimensions, and could only be fully appreciated from drawings of the parts in question. At the other extreme a few broad principles might be laid down, based on the extraordinary demand at the present time for steel and non-ferrous metals, especially aluminium and brass. Thus, the replacement by cast iron of all-welded structures which formerly were made in cast iron or which were initially designed as weldings could be considered, and also the replacement of castings in aluminium alloys, magnesium alloys, bronze, gunmetal, and other non-ferrous metals, where they can be dispensed with, and which have to be conserved for purposes for which they are indispensable. The wider use of austenitic irons and martensitic irons in place of certain ferrous and non-ferrous alloys might also be mentioned. It is assumed that under present conditions the steel and non-ferrous industries will appreciate the assistance cast iron can give in relieving pressure on production.

Mr. Pearce has chosen an intermediate plan, and has classified the field of replacement available into four sections, as follows :—

Section 1.—War and defence purposes.

Section 2.—The building industry and domestic castings —i.e., castings used on, in and about buildings of all descriptions, including civil engineering and public works generally.

Section 3.—The engineering industry.

Section 4.—Other industries for which lists such as that given in Section 3 might be prepared.

For obvious reasons no details are given in Section 1, but it can be said that the war and defence demand affects both sides of the industry—that is, the light or builders' castings side and the heavy or engineering castings side. In some cases cast iron is being used because it is the most suitable material for the purpose, while in others it is used in part because of the strain on the productive resources of other materials. It is in this field that foundries normally catering for the building and domestic trade can made good deficiencies due to the decrease in normal demand.

In the other sections a considerable amount of replacements is detailed in the paper, based on that originally prepared by the British Cast Iron Research Association for the Ironfounders' National Confederation, and elaborated from suggestions received by the latter body from a number of firms.

The question of providing an article in cast iron to replace another material is essentially a technical one. It involves design, manufacture, frequently under controlled conditions, testing and results of service life, showing a comparison of ratio of cost to life for the two materials. While the cheapest and most readily available materials for the purpose should be used, the copy of a part in common cast iron may prejudice the material if trouble ensues, and where other conditions prevent any modification to design, special cast irons may be called for.

For these reasons users of castings requiring replacements in cast iron should be invited to supply a print of the part to be replaced and indicate whether, and to what extent, redesign is possible. Hence the most complete co-operation should exist between the casting designer, founder and metallurgist. The success of replacement largely depends upon this co-operation. Many foundries do not possess all the elements of this, and some competing products, such as plastics and cement, offer the kind of information required by would-be users, through a central body. The B.C.I.R.A. possesses the nucleus of a design section capable of advising on this aspect of substitution, and with its expert services relating to foundry production, experimental foundry and laboratories, enabling any property of interest to users to be determined, is in a position to aid those who are interested in extended uses. The existence of national specifications for cast iron, 309/1927, 310/1927, 821/1938, and particularly 321/1938 and 786/1938, in the formulation of which the Institute of British Foundrymen played no small part, has been of the very greatest assistance in replacement work.

Readers need have no hesitation in seeking the assistance to which Mr. Pearce refers, particularly in the choice of a composition which is most likely to satisfy the conditions demanded for any particular replacement. It should not be overlooked that during recent years an enormous amount of work has been done by the British Cast Iron Research Association to increase the range of materials classified as cast iron, but possessing properties not generally associated with this material. Almost any metallurgical structure can be obtained in a wide range of strength, while, in addition, production methods have been greatly improved, not only in regard to precision of form, but in the uniformity and soundness of the product.

Recovery of Metals from Scrap and Waste

EXCEPT for a few metals, such as zinc and tin, only a relatively small part of the metals used can never be reclaimed. Obviously, therefore, real conservation can be achieved by promoting the constant use and re-use of that part of production which is not destroyed in service. Thus, the recovery of scrap and wastes, and their use with or instead of metals produced from ores, is sound economics in normal times, and entirely in accordance with the general principle of conserving natural resources. Under the present emergency conditions, however, the recovery of metals from scrap and wastes has a more vital importance, and all possible steps should be taken to ensure that recovery is complete.

Many important works throughout the country have brought the salvage of waste material to a high state of efficiency, and the amount of valuable metal and other products, saved yearly by foresight and ingenuity, is valued at thousands of pounds. Mention may be made of the large works of Wolseley Motors Ltd., for instance, where swarf from the machine shops yields a huge monthly tonnage after being cleaned and sorted.

The "Swarf Deck" at the works of Wolseley Motors Ltd. where scrap and waste metal is treated for re-use.

Normally, this swarf comprises a mixture of oil and two or three different metals. This is charged into separators which rotate at a high speed and expel the oil from the swarf by centrifugal force through perforated sides. Clean and free from oil the swarf is removed, and if it comprises one metal it can be compressed into convenient forms and despatched for remelting. On the other hand, when the swarf comprises both ferrous and non-ferrous metals it is passed through a magnetic separator.

Recovery of metal and wastes is now carried out under adequate technical control which facilitates the production of reliable secondary non-ferrous metals which for many purposes will serve equally as well as primary metals. In the present emergency it is essential that the collection of scrap and wastes should be efficiently organised, and, if there is not sufficient to justify cleaning and sorting, it should be despatched to some reliable firm for conversion into usable materials.

At the works of Wolseley Motors Ltd. the salvage department is responsible for the collection and re-use of surplus material. The salvage, which includes nickel and other steels, copper, phosphor-bronze, aluminium and aluminium alloys, is carefully sorted either by hand or machinery, and even the oil cleaned from the metal is purified and re-used in the machine shops.

The demand for scrap metal in the steel industry continues unabated, and as the efforts to manufacture more steel develop, the call for scrap will become intensified. In normal times shipbreakers provide large quantities of scrap, but under present conditions vessels which would have been dismantled in peace-time are being reconditioned for further service, consequently very little scrap is being obtained from this source. Large shipments of scrap have been received from abroad, but it is obvious that the more scrap is released in this country the more will shipping be available for other essential transport purposes.

There are, of course, thousands of tons of metal in the streets of most towns which could be used for scrap when the emergency becomes very acute, but there must be many factories and industries where no real effort has yet been made to collect the quantities of scrap, obsolete plant and unwanted materials which have accumulated over many years. Steps should be taken to collect these materials, without delay, they will be promptly taken up at control prices.

British Standard Specifications

Hardness Testing

Hardness testing forms a convenient means of controlling heat-treatment, case-hardening or similar surface treatment of metals, and there has been increasing demand for a direct reading test (Rockwell type) which enables rapid routine tests to be made.

The need for a standard for such a test has become more and more apparent, and in response to representations from a wide field of engineering the British Standards Institution has prepared and issued the above standard.

The standard forms an addition to British Standards on Hardness testing, which have already been published, namely, B.S. 240, Brinell Test; B.S. 427, Diamond Pyramid Test; and B.S. 860, Approximate Comparison of Hardness Scales. In the new standard for the Rockwell test it is explained that in addition to standardising the manner in which the test is made it has been necessary to include requirements relating to the machine itself, as the accuracy of the test is largely dependent upon the accuracy of the machine.

The standard only includes three scales, A, B and C, and the ranges of materials with which these scales may be used are indicated in an appendix, in which there is also a note about scales D to H and the uses to which they are put.

A simple means of checking the accuracy of the machine by means of a calibrated steel block is also described.

In view of the extent to which the Rockwell Test is being used, the new, standard will be welcomed by industry.

Metal Arc-Welding

The revision of B.S. 538—Metal Arc Welding of Steel Structures—has been awaited by industry for some time, and its publication is both welcome and opportune.

It had been known that the main object of preparing this revision was to bring the standard into line with the conditions issued by the London County Council under which welding would be permitted in London.

There is, accordingly, very much which is common in both documents, but the British Standard is somewhat more comprehensive in that it deals in greater detail with the important aspects of workmanship and testing.

Copies may be obtained from the British Standards Institution, 28, Victoria Street, London, S.W. 1, price 2s. each (2s. 3d. post free).

The Institute of Physics

At the annual general meeting of the Institute of Physics, held on Wednesday, June 5 last, the following were elected to take office on October 1, 1940:—President, Prof. W. L. Bragg; vice-president, Dr. B. A. Keen; honorary treasurer, Major C. E. S. Phillips; honorary secretary, Prof. J. A. Crowther; new members of the Board, Prof. E. A. Owen and Dr. C. Sykes; Prof. G. I. Finch (appointed by the Physical Society); and Dr. R. W. Lunt (appointed by the Faraday Society).

Fatigue, with Reference to Wrought Aluminium Alloys

By G. Forrest, B.Sc.

(Research and Development Department, Northern Aluminium Company, Ltd.,)

No attempt has been made in this article to review in detail the large quantity of work which has been done on the fatigue of wrought aluminium alloys. The following comments, therefore, deal only with those characteristics which appear to the author to be of greatest importance.

Existence of a Limiting Safe Range of Stress

IT is well known that for steels in general, a definite limiting safe range of stress exists—i.e., ranges of stress below this value may be applied indefinitely without causing failure.

Many non-ferrous metals, including aluminium alloys, do not show any such limiting stress range; the stress-number of cycles to failure curve apparently continues to drop even up to 500 or 1,000 million cycles. This has been conclusively proved by Templin,[1] Johnson and Oberg[2] and others. From this point of view, Johnson and Oberg's work is of particular interest. In addition to testing to 500 million cycles, at which endurance the S/log N curve has not become horizontal, they retested unbroken specimens at a higher stress to determine whether the latter showed signs of "damage" caused by the original applications of stress. Specimens of a duralumin type alloy first tested at ± 5·4 tons per sq. in. for 200 million cycles, when retested at ± 8 tons per sq. in. broke at average endurances slightly less than those indicated by the original S/log N curve. Johnson and Oberg drew the conclusion that the original stress ± 5·4 tons per sq. in. was above the limiting fatigue range for the material.

Variation of Results from Different Sources

In view of the continued fall of the S/N curves up to the maximum endurances tested, it is customary for investigators to fix an arbitrary number of stress cycles on which to work, and to quote results on this basis. Westhoff[3] has expressed the opinion that this method of quoting results is insufficient and that comparison of fatigue results given by various investigators is impossible unless the actual S/N curves are given. He points out that a result based on 20 million cycles may be 60% higher than the value obtained by continuation of the curve to 1,000 million, and also that the curves of two different alloys may intersect so that tests of different lengths may give contrary results.

It is not safe, however, to assume that variation of results from different sources is due solely to the difference of endurance basis on which testing has been carried out. Test results are also dependent on other factors (which affect aluminium alloys in common with other materials), such as the surface finish, form and size of test-piece, type of stressing action, and speed of testing.

Regarding the effect of different types of stressing action, Gough and Sopwith[4] have made tests under direct stress (using Haigh machines) and rotating bar conditions on a sample of duralumin (among other materials). They found a reduction of strength under axial load of 3 to 27%, as compared with values from rotating bar tests. Westhoff quotes results from another source, in which occurred a reduction under direct stress of 10 to 20% in comparison with rotating bar tests. Such apparent increase of fatigue strength in rotating bar tests is considered to be due to two causes. In the first place, the assumption of perfect elasticity in the stress calculation for rotating bar tests may, in materials which depart widely from purely elastic conditions within the fatigue range, give a falsely high estimate of the stress (Mason and Inglis[5]). Secondly, the volume of material under test is very much greater in a direct stress than in a rotating bar test, where only the surface skin is stressed up to the maximum value.[6] The writer considers the second factor to be of major importance as regards heat-treated aluminium alloys.

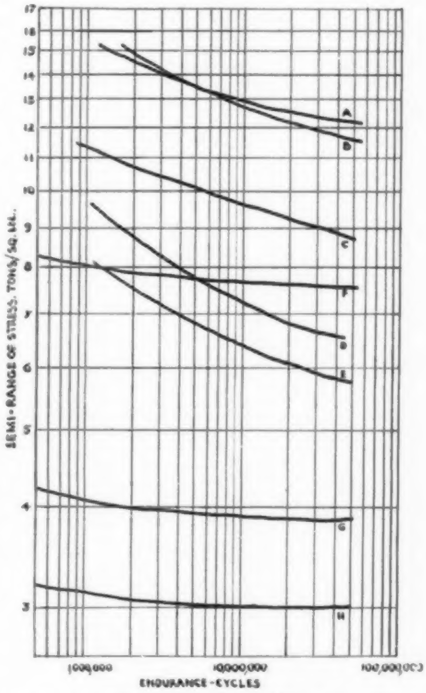

Fig. 1.—Fatigue test results on some wrought aluminium alloys.

Regarding the effect of speed of testing, Jenkin and Lehmann,[7] who investigated various materials up to a speed of over one million cycles per minute, found a general increase of strength for rolled aluminium with increasing frequency. More recently, Krouse[8] showed for duralumin an endurance limit of ± 6·7 tons per sq. in. at 1,500 and 10,000 r.p.m., and ± 7·6 tons per sq. in. at 30,000 r.p.m. (The tests were made on a 500 million cycle basis.)

Information appears to be scarce on the effect of various workshop finishes on the test-pieces, but Sutton and Taylor[9] have shown that unsuitable etching may reduce the fatigue strength of a sample of duralumin as much as 31%. The effect of variation in size of test-piece is likely, to be small over the range of test-piece sizes generally used, but the effect would be of importance in the translation of test results into engineering practice. In general, a large mass of material may be expected to show a less favourable result than a small one.

The causes of variation have not been by any means exhausted. Enough has been said, however, to indicate the impossibility of obtaining satisfactory comparison of fatigue values from different sources except where very close standardisation of testing has been carried out. In general, it is safer to accept the results of any investigation as complete in themselves and not comparable with results from other sources. Further, the quotation of a fatigue strength as a fundamental property of the material and independent of the above test conditions does not appear at present possible.

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[1] R. L. Templin. *Proc. Amer. Soc. Test. Mat.* 1933, 33, II.

[2] J. B. Johnson and T. T. Oberg. *Proc. Amer. Soc. Test. Mat.* 1929, 29, II.

[3] H. Westhoff. *Z. Metallkunde.* 1938, 30 (8), 258-265.

[4] H. Gough and D. G. Sopwith, *J. Iron & Steel Inst.*, 1933, 127, 301–332.

[5] W. Mason and N. P. Inglis. Aeronautical Research Committee, R. and M. No. 1126, 1927.

[6] Editorial. *Metals and Alloys.* March, 1940.

[7] C. F. Jenkin and G. D. Lehmann. *Proc. Roy. Soc.* A. 125, 1929.

[8] G. N. Krouse. *Proc. Amer. Soc. Test. Mat.* 1934, 34, II.

[9] H. Sutton and W. J. Taylor. *J. Inst. Met.* 1934, 55, 149.

Variation of Fatigue Properties with Class of Alloy

Fig. 1 shows a group of fatigue test results on some wrought aluminium alloys. The results were obtained on rotating cantilever testing machines (single-point loading) at a speed of 3,000 cycles per minute. Test-pieces consisted of a parallel portion of diameter 0·3125 in. joined by fillets of radius 1 in. to enlarged ends. Thus the maximum stress was applied to only a small region of material at the base of the fillet radius.

The chemical compositions of the various samples are recorded in Table I. All the materials were received in the form of 1 in. diameter extruded bar, so that the details of manufacture were as far as possible constant. Table II gives the tensile properties of the samples used and the stress ranges under fatigue corresponding to an endurance of 50 million cycles. The endurance ratios $\frac{\text{semi range of stress}}{\text{ultimate stress}}$ are also recorded. It is obvious from Fig. 1 that extension of the S/N curves would alter the relative values of these quantities, but it is considered that the tests have been of sufficient length to justify the comments made.

TABLE I.

Chemical Composition.

Material.	Cu. %.	Fe. %.	Mn. %.	Mg. %.	Si. %.	Cr. %.
A	4·35	0·53	0·64	0·64	0·61	—
B	4·19	0·73	0·77	0·46	1·01	
C	1·64	0·53	0·26	0·45	0·64	
D	0·01	0·31	0·02	0·65	1·20	
E	0·03	0·34	0·03	0·61	0·34	
F	0·01	0·23	0·01	2·36	0·20	0·26
G	0·01	0·35	1·32	—	0·30	
H	0·01	0·34	0·01	—	0·23	

A = Single heat-treatment alloy.
B, C, D, E = Double heat-treatment alloys.
F, G, H = Non-heat-treated alloys.

TABLE II.

Mechanical Properties.

Material.	0·1% Proof Stress, Tons per Sq. In.	Ult. Tensile Stress, Tons per Sq. In.	Elongation % on $4\sqrt{\text{Area}}$.	Endurance Limit, Tons per Sq. In. (50,000,000 Cycles).	Endurance Ratio = $\frac{\text{Semi-range of Stress}}{\text{Ult. Tensile Stres.}}$
A	22·6	34·8	16½	± 12·2	0·35
B	31·1	34·7	9	± 11·5	0·33
C	18·9	23·9	18	± 8·8	0·37
D	18·3	20·0	12	± 6·5	0·32
E	12·5	15·3	25	± 5·7	0·37
F	3·75	12·0	39	± 7·6	0·63
G	2·5	6·75	46	± 3·9	0·58
H	2·1	4·9	49	± 3·0	0·61

The alloys quoted consist of two high-strength alloys, both depending on heat-treatment for their properties, one requiring a single heat-treatment and the other a double heat-treatment; four medium strength alloys of which three require double heat-treatment and the fourth no heat-treatment; and two low-strength non-heat-treated alloys.

All the curves are of the form generally associated with aluminium alloys—i.e., they are smooth and with no definite change of slope, such as is usually obtained with ferrous metals. None of the curves becomes horizontal within the range of endurances tested (with the possible exception of material H—commercially pure aluminium—in the "as extruded" state). The main difference to be observed between the different classes of alloy is that in each case the slope of the curve for heat-treated alloys is very much greater throughout than for those not dependent on heat-treatment. A further difference, which is not shown on the curves, is that the scatter of individual results on the heat-treated materials was considerable, particularly on the high-strength ones. (The curves were drawn approximately through the centres of the fields of scatter.) The scatter on the non-heat-treated materials was small. The results of individual tests have not been shown for the sake of clearness in the diagram, and because, in the case of materials A and B, the curves are mean curves from six complete determinations on different samples. Regarding materials A and B (a duralumin type alloy involving a single heat-treatment, and a double heat-treatment alloy) which had closely similar ultimate stress values, it will be noted that the curves are also closely similar.

Reference is made to the column "Endurance Ratio" in Table II. The alloys depending on heat-treatment for their properties have given values lying between 0·32 and 0·37, the non-heat-treated alloys, values between 0·58 and 0·63. These values are directly dependent on the length of test utilised and lower values will be obtained throughout by increasing their endurance basis. Although considerable variation of ratio is obtained within each group, there is a distinct and much greater difference in value between the two groups. Increase of the endurance basis would cause this difference to become greater. (Templin's results on a large series of aluminium alloys indicated that heat-treatable alloys in the annealed state gave endurance ratios of a similar order to the non-heat-treatable alloys, although heat-treatment always increased the actual endurance limit at 500 million cycles.)

Comparison of the above results with those of ferrous materials is difficult, owing to the extremely large variety of the latter. Endurance ratios for steels tested on rotating bar machines have been recorded at least as widely as 0·34 and 0·67,[10] and an average value probably lies between 0·43 and 0·50.

The actual values of endurance limit shown in Table II may in some cases be regarded as high for these materials. For example, the value quoted for material A is above the values usually quoted for duralumin type alloys. The tensile strength of the sample is, however, also high and the endurance ratio becomes normal. The tensile strength of extruded material to B.S.S. 6 L. 1 may vary, due to one or more factors depending on variation in manufacturing technique or type of section. We have no definite knowledge that the endurance ratio remains constant with alteration of all the variables, but from these which have been investigated there is no evidence of any great reduction. (It is assumed that the material has been subjected to satisfactory heat-treatment and has not been overheated.)

Fatigue of Specimens with Surface Discontinuities

It has long been realised that a knowledge of the relative fatigue strength values of different materials from tests on polished specimens is totally inadequate even to allow comparison of different materials for a particular structural part, since, when materials fail under fatigue conditions in practice, failure is nearly always at parts where stress conditions are not simple—that is to say, where sudden changes of section occur, such as screw threads, holes, joints in general, also where surface damage has been sustained, due to mechanical action, where some other material is in contact with the component or where conditions of intense corrosion are active.

As a consequence, a considerable quantity of work has been done utilising specimens containing discontinuities such as notches and holes. Here again it is unfortunate that no figure which is a function purely of the material and independent of a large number of conditions of test can be given. It has been considered by some investigators that the damping capacity of a material at amplitudes corresponding to the fatigue range of polished specimens would give such a figure as indicating the power of a material to redistribute stress at a region of stress concentration for an unlimited number of stress cycles. Such a figure would undoubtedly give very valuable information on the above problem, but information on notch sensitivity based on damping capacity alone would be very misleading in some cases. This point will be referred to later. A word here is necessary on attempts to correlate notch sensitivity under fatigue conditions with elongation values as obtained by a tensile test. No success has been obtained by such attempts, and from theoretical considerations there appears to be no reason why any relationship should exist regarding fatigue values under reversed stresses—i.e., with zero mean stress of the cycle. Under conditions where the fatigue range is not reversed, but where a mean stress not equal to zero is present, the ability of the material to deform plastically during the first few stress cycles may be of importance. A similar point is discussed by Fischer.[11]

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[10] H. J. Gough, "Fatigue of Metals," pp. 296-297. (Earnest Benn, Ltd. 1926.)

Referring to actual tests on notched test-pieces, some results quoted by Templin in 1933 appear to the writer to be of great importance. Results from a heat-treated duralumin type alloy and two alloys not subject to heat-treatment were reported, both tested with sharp V notches. The reduction of strength due to the sharp V notch was very much less for the heat-treated alloy than for the other two materials, even when the latter were in the annealed condition. The reduction of endurance limit due to the notch was 40% for the duralumin type alloy and 68% and 71% for the other two alloys in the annealed states. When the latter alloys were cold-worked to a three-quarter hard state by drawing, the reductions were 88% and 83%. Templin does not give the theoretical stress concentration factor for his notch, but it is obvious from these results that the heat-treated alloy has shown comparatively low notch sensitivity. This fact is of considerable importance, particularly since it appears probable that the damping capacity for duralumin type alloys may be low. Results from other investigators are in agreement on this point. Krouse, using V notches on a selection of materials consisting of four steels, two cast irons, brass and a duralumin type alloy, quotes results that indicate that the latter was less notch sensitive than the others, except for the cast irons. Further, Irmann[12] has reached the conclusion that aluminium alloys in general compare favourably with alloys of magnesium and copper, and also ferrous metals, with regard to the effects of both mechanical and chemical surface damage.

So far the main points mentioned have been :—(1) The lack of development of a definite limiting range of stress, even at long endurances. (2) The low endurance ratio for heat-treated alloys and the relatively high endurance ratio for alloys without heat-treatment. (3) The large scatter of results for heat-treated alloys. (4) The difference between endurance limit under rotating bar conditions and direct stress of duralumin. (5) The relatively low notch sensitivity of a duralumin type alloy, although the damping capacity is probably small.

Attention has been drawn[13] in the literature on fatigue to the effect of "internal notches." It appears probable, in fact, that the explanation of fatigue phenomena in general may lie in the understanding of the behaviour of material containing various types of internal inequalities, such as to produce stress concentration effects within the material. If the above results are regarded in the light of these suggestions, it appears that the low endurance ratio of heat-treated wrought alloys obtained, using polished specimens, may be explained at least in part by the assumption of an internal stress concentration effect of a magnitude greater than would be expected for most ferrous metals, and inseparable from the effect or heat-treatment. Such a supposition would be consistent with the low notch sensitivity obtained by comparison of notched with unnotched specimens, and the difference of value between rotating bar and direct stress results. It is open to criticism on various grounds, however; for example, the scale of size and distribution of stress concentrations which might be expected to account for these phenomena are difficult to visualise in terms of alteration of structure due to heat-treatment. From the practical point of view, it may be pointed out that the bias in certain quarters against heat-treated aluminium alloys on the grounds that the endurance ratio is low is largely unjustified, since the notch sensitivity is also comparatively low. Further, the author has been unable to trace, in the published literature, any evidence of failure occurring due to fatigue of aluminium alloys in aircraft.

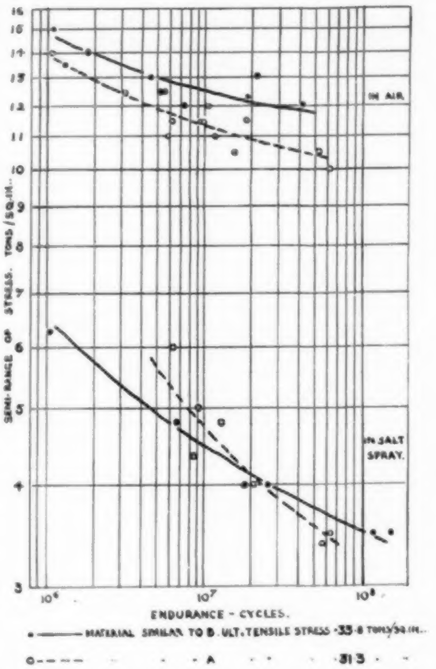

Fig. 2.—Fatigue test results on two wrought aluminium alloys tested in a continuous salt spray.

Corrosion Fatigue

It has long been known that the effects of corrosion and fatigue applied simultaneously are extremely serious, very much more serious in general than the sum of the effects applied separately. There would be no useful purpose served in the present context by quoting individual results since such results are dependent on so many variables. Comparison of duralumin with various other materials used in aircraft construction may be found in further work by Gough and Sopwith[14] and elsewhere.

One point which may usefully be emphasised is a conclusion reached by Irmann that the normal relative corrosion resistance of aluminium alloys is masked under corrosion-fatigue conditions. In this connection Fig. 2 may be of interest. It shows curves produced from rotating bar tests at 3,000 cycles per minute in a continuous very fine spray of 3% NaCl, and concerns samples of alloys A and B (see Tables I and II), the first being a single heat-treatment duralumin type alloy, and the second a double heat-treatment alloy, the normal corrosion properties of the latter type being generally considered to be inferior to those of the single heat-treatment alloys.

It appears from the results that the normal corrosion properties have not been reflected in the corrosion-fatigue tests since the difference between the two materials is extremely small when compared with the decrease in strength due to the corrosion.

It may be pointed out that this reduction in strength is by no means excessive when compared with other engineering materials. As a consequence of this reduction of strength due to corrosion fatigue, material used in practice is nearly always protected by surface coatings. Gerard and Sutton[15] have shown that by suitable protection, the endurance limit of the material in salt spray may be even higher than the unprotected material in air.

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[11] G. Fischer. *Jarbuch der deutscher Luftfahrtforschung.* 1938. Vol. I, pp. 517-523.

[12] R. Irmann. *Aluminium.* 1935, 17 (12). 638-643.

[13] H. Wiegend. *Metallwirtschaft.* No. 4, Jan., 1939.

[14] H. J. Gough and D. G. Sopwith. *J. Iron and Steel Inst.* 1937, 135, 293-313.

[15] I. J. Gerard and H. Sutton. *J. Inst. Met.* 1934. 56, 29.

Alloys of Rare and Precious Metals

Many rare and precious metals, because of the distinctive properties they confer on other metals, are contributing to the development of alloys for special purposes. Brief reference is made to some of these developments and their applications.

As industrial technique becomes more complex, more refined and exact, rare and precious metals, with distinctive properties, are being applied to a wide range of purposes in the form of alloys, and some recent developments in this metallurgical field are of interest.

Dental alloys.—The tendency to discolour of alloys in which silver and zinc predominate can be overcome with the aid of small percentages of platinum or palladium. Such alloys also possess the advantage in dental work of being amenable to hardening by thermal treatment, whereas the silver-zinc alloys alone cannot be hardened in this way. A small percentage of gold is just as effective as platinum or palladium in making the alloys resistant to discoloration in the mouth, but the silver-zinc-gold alloys cannot be heat-hardened. On the other hand, the simultaneous use of gold and palladium or platinum does not suppress this quality, and a typical alloy for dental work may contain 75% silver, 17% zinc, 5% gold and 3% palladium.[1]

Other silver-containing palladium alloys have been developed which are notable for a very high percentage of palladium and a relatively small proportion of platinum. Highly resistant, hard and easily workable alloys are thus obtained in which the palladium and platinum together make up more than 55% of the total alloy, and the platinum content is 15% or more of the palladium content (e.g., 48·33% palladium, 10% platinum and 41·67% silver). Such alloys are exceptionally resistant to tarnish and nitric acid, and are not attacked by hypochlorite antiseptics. They are consequently of particular value in dental mechanics. Similar ternary alloys with a somewhat lower platinum content (9% or more of the palladium content) are more suitable for jewellery and electrical equipment.[2]

Palladium also predominates in another series of dental alloys characterised by the presence of 15% to 50% platinum and 5% to 20% gold, together with traces of other rare metals. They possess the ductility of platinum, and after shaping into wires, sheets, etc., exhibit a brilliant finish in contrast with the dull surface of gold-palladium alloys. Alloys containing, for example, 59% palladium, 30% platinum, 10% gold and 1% rhodium (or 58% palladium, 30% platinum, 10% gold, 1% rhodium and 1% iridium) are resistant to boiling nitric or hydrochloric acid, in spite of the ready solubility of palladium or palladium-high alloys. Their value in dentistry is enhanced by their good adhesion after baking on porcelain, and they also find application in the production of fountain pen nibs and chemical apparatus.[3]

Silver alloys which are again notable for the high palladium content have been produced for the purpose of coating chromium-nickel alloys or stainless steels used in dental crown and bridge work in order to facilitate soldering. An example contains 20% to 23% palladium, 1% to 2% gold, 1% zinc and 78% to 82% silver.[4]

Hard platinum alloys.—Earlier methods for hardening platinum, especially in the hot condition, have been attended by certain drawbacks. Alloying with iridium, osmium or ruthenium is effective, but entails the use of 5% to 10% or more of these costly metals. Nickel, again, serves the purpose, but detracts from the chemical resistance. A more economical process of recent discovery consists in alloying platinum with only 0·05% to 5% zirconium, which has the further advantage of imparting a fine-grain structure and does not lead to embrittlement at high temperatures. Unlike the platinum-iridium alloys, moreover, the platinum-zirconium alloys can easily be soldered to platinum-gold alloys. Adhesion to porcelain and other ceramic masses is good. Exceptional hardness is secured with the aid of other precious metals: an alloy with 1% rhodium and 0·5% zirconium possesses a Brinell hardness of over 100°.[5]

Hard gold alloys.—It is interesting to note that a very small percentage of beryllium substantially increases the hardness of gold without materially affecting its chemical resistance. An alloy with 0·1% beryllium raises the Brinell hardness from 25° to 50°, while, 0·7% beryllium leads to a Brinell hardness of over 100°. The higher percentage, however, is liable to result in brittleness owing to the formation of Au_3Be, and the best all-round improvement without sacrifice of chemical and physical qualities is achieved with the aid of smaller amounts of beryllium.[6]

Alloys of nickel and precious metals.—Tantalum has the property of forming heat-hardenable alloys with nickel when present to the extent of 8% to 25% A relatively soft alloy is formed in the first place from which objects like dental plates can be prepared and afterwards rendered extraordinarily hard and tough by the usual process of heating, rapid cooling and reheating.[7]

Nickel-niobium alloys containing up to 11% to 12% niobium (this is the limiting concentration of niobium in nickel at 900° C.) are stated to show improved resistance to attack by hydrochloric acid.[8] Other nickel alloys distinguished by great resistance to corrosion contain 25% to 80% rhodium.

Alloys with indium.—Many alloys used in friction-bearing surfaces can be made more resistant to acid corrosion by incorporation of 0·1% to 1% indium. Systems improved in this manner include cadmium-copper, cadmium-nickel, cadmium-silver, cadmium-cobalt, cadmium-magnesium and lead-copper.[10]

A recent investigation of the properties of tin-indium alloys revealed their extreme malleability and relatively high resistance to fatigue. Indium is soluble in tin to the extent of 1·5%, while tin is soluble in indium to the extent of 10%.[11]

Sintered alloys.—Tungsten carbide masses containing about 3·7% carbon and up to 20% iron, cobalt or nickel acquire a finer structure after incorporation of 1% to 30% carbide of vanadium, niobium or tantalum, and thus give longer service when used as drawing blocks, etc.[12] Improved cutting wheels are prepared from tantalum carbide by sintering in a hydrogen furnace at 1,300° C. for 1½ hours with 2·7% to 18% iron, cobalt or nickel and 0·3% to 2% aluminium.[13]

Rayon-spinning nozzles.—Gold-platinum alloys with a small content of rhodium have been used for rayon-spinning nozzles, e.g., 45% to 60% platinum, 52% to 37% gold, and up to 3% rhodium.[14]

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[1] G.P. 670,725, Dresdner Gold- und Silberscheideanstalt Fritz and Co. G.m.b.H.

[2] U.S.P. 2,129,721, International Nickel Co. (E. M. Wise).

[3] U.S.P. 2,107,310, American Platinum Works (J. S. Streicher).

[4] Austrian Pat. 152,138, H. Altmann.

[5] G. P. 670,897, W. C. Heraeus G.m.b.H. (K. Ruthardt).

[6] G.P. 674,933, W. C. Heraeus G.m.b.H.

[7] G.P. 678,535, W. C. Heraeus G.m.b.H. (W.Rohn).

[8] Pogodine and Zelikmann, *Metallourg.*, 1939, 8-11.

[10] F. P. 831,256, General Motors Corporation.

[11] Fink, Jette, Katz and Schnettler, 75th Gen. Meeting Electrochem. Society, Columbus, 1939.

[12] G.P. 668,861, F. Krupp A.-G.

[13] G.P. 670,725, Allgemeine Elektrizität -Gesellschaft.

[14] FP. 825,70[illegible], G. Siebert G.m.b.H.

The Use of Salt Baths

By W. Nelson, B.Sc., Dipl. R.T.C.

Fused salts may be made up to cover a wide range of temperatures, from as low as 150° C. for tempering to as high as 1,400° C. for hardening high-speed steel. In addition to freedom from atmosphere attack, components treated in a suitable salt bath are more rapidly and uniformly heated to a required temperature, than when they are heated by radiation, without overheating. This article is devoted almost entirely to the use of salt baths in the heat-treatment of ferrous metals.

THE salt bath was originally used for the scale-free hardening of such articles as engraving dies, where freedom from scale is essential, and for many years was used for little else. Even to-day there are many who regard the salt bath method as a makeshift, only to be used for such jobs as cannot conveniently be hardened by other means. This is unfortunate, since the method offers a degree of control which is practically unique. This control is simple to exercise, but it is nevertheless necessary, and, without it, indifferent results will be obtained.

Salt baths may be divided into two classes, namely, those which contain cyanide, and those which do not. The word " cyanide " is here used to include cyanamides and HCN polymers, all of which provide the cyanogen radicle in the melt. The cyanide-free baths may be subdivided into high- and low-temperature baths. Only steel, iron and aluminium alloys are treated on a large scale at present in salt baths, although the method is being developed for other non-ferrous alloys, and is already used on a small scale for the precious metals. This article is devoted almost entirely to the treatment of ferrous metals.

The cyanide and non-cyanide baths have much in common. The principal characteristics are well known. These are freedom from scale of the treated article, high rate of heating of the immersed parts, and accurate temperature control. The great difference between these two types is that the cyanide bath normally carburises, but may decarburise, while the cyanide-free bath tends to decarburise.

The use of the cyanide bath for carburising is widely known and practised, but its advantages and limitations as a heat-treating medium are not so generally appreciated.

Carburising

When the cyanide bath is used for carbusing it should contain between 30% and 50% NaCN. A weaker bath gives unsatisfactory carburisation, and baths containing more than 50% NaCN are expensive to maintain. The higher the NaCN content of the bath, the deeper is the glasshard zone of the case, although the total depth is not much affected by the cyanide strength between the above limits. The modern tendency is to disregard the total depth of a case and to consider only the useful, or glass-hard, part. When regarded in this light, the difference between a 30% and a 50% bath is marked. A case produced in the former will stand little, or no grinding, whereas nearly half of the 50% bath case may be ground away before the hard zone is removed.

For some parts a superficially-hard case is sufficient, and for these a 30% bath may be used. If, however, any grinding is to be done, or if the part has to stand a considerable load, the 50% bath must be used. The important fact is that once the optimum bath strength for a given job is determined, the strength must be maintained at the suitable figure.

The control of bath strength is not the difficult and laborious business that many imagine it to be. It is an extremely simple analytical operation, and need not be done frequently in all cases. When production hardening is being done, the operator will soon learn, from tests, how much cyanide is required daily. When this is established, the daily tests may be dicontinued, and a weekly check should be sufficient to ensure that all is in order. Most large-scale operators carry out daily tests on the bath strength in the interests of economy, so as to avoid unnecessarily large additions of NaCN.

Although deep carburising can be done in the simple cyanide bath, more complicated mixtures are being used nowadays. These are known as " accelerated " baths in America, and by various trade names in this country. They consist of mixtures of varium and strontium chlorides and sodium cyanide. They are all proprietary compounds, and are patented. The advantage of such baths over straight cyanide are increased rate of penetration and a deeper saturated zone. To obtain the best results from these baths, chemical control is essential. With chemical control consistently satisfactory results are assured. Without control, trouble will be experienced. The method of control is the same as for the cyanide bath, with minor modification.

There is a widespread impression that cyanide baths are only suitable for conferring cases up to 0·015 in. The simple cyanide bath can do much better than this, while the accelerated or activated baths are regularly used for carburising to 0·06 in., and under certain conditions to confer really deep cases such as 0·1 in. and 0·25 in. Tables and charts are published by several chemical manufacturers showing the conditions required to obtain such case-depths.

The conditions governing rate of penetration may be summarised as follows :—

1. *Composition of Bath.* This is supremely important. It can, and must, be chemically controlled, in order to obtain satisfactory and consistent results.

2. *Temperature of Carburisation.* To obtain the desired depth of case, it is necessary to keep the temperature constant. If fluctuations below the specified heat are permitted, the full depth of case will not be realised.

3. *Analysis of Steel.* Certain alloying elements promote, and others hinder, carburisation. The rate of penetration obtained on 2S·14 steel is not the same as on S·82, for instance.

4. *Grain Size.* Some observers maintain that fine-grained steels carburise more slowly than the coarse grained.

The above four principal factors can all be controlled within limits. When long carburising periods are in question, however, small variations are multiplied, and it is somewhat difficult to forecast exactly what case depth will be obtained after such periods. For this reason the figures in the following table are approximate above a certain point, and a guide only.

TABLE I.

Case Depth Obtained in Accelerated Cyanide Bath

Temperature .. 950° C.
Steel.. .. .. 2S·14

Hours.	Case Depth.	
1	0·025 in.	
2	0·035 in.	
3	0·045 in.	
4	0·052 in.	
5	0·058 in.	
10	0·080 in.	Approx.
20	0·110 in.	
30	0·150 in.	
100	0·250 in.	

The difficulty of forecasting exactly the depth of case on a large component would be a serious handicap, if it were not for the fact that the mass of a job does not affect its rate of carburisation. Thus, ⅝-in. diameter test-pieces can be treated along with a 6-in. diameter ram, and the case on these test-pieces shows how carburisation is proceeding. The case on the large component is the same as that on the small-diameter "spy," since the time of carburisation to the same depth is the same for all sizes of component.

Heat-Treatment

Both cyanide and cyanide-free baths are used extensively for heat-treatment. While it is known that the latter may decarburise, it is not generally known that even a cyanide-containing bath may decarburise. Table II shows the effect of a weak cyanide bath on a 0·28% C. steel.

TABLE II.

Strength of bath .. .. 8% NaCN
Carbon content of steel .. 0·28%
Temperature .. .. .. 850° C.

Depth Below Surface.	Carbon Content after ½ Hour.	Carbon Content after 1 Hour.
0·003 in.	0·24	0·21
0·006 in.	0·26	0·25
0·009 in.	0·27	0·26
0·012 in.	0·28	0·27

On the other hand, even a weak bath can exercise a slight carburising action on a low-carbon steel, as shown in Table III.

TABLE III.

Strength of bath .. .. 15% NaCN
Carbon content of steel .. 0·15%
Temperature .. .. .. 950° C.
Time of treatment .. .. 4 hours

Depth Below Surface.	Carbon. %
0·003 in.	0·30
0·006 in.	0·26
0·009 in.	0·25
0·012 in.	0·24*d*
0·015 in.	0·23
0·018 in.	0·20
0·02 in.	0·19
0·024 in.	0·15

This degree of carburisation is insufficient for proper casehardening, but it is sufficient to upset mechanical tests in some instances.

It is possible to adjust the cyanide strength to be neutral to steel of a given carbon content, for heat-treatment purposes. The rule is that the NaCN content of the salt should be 50 times the carbon content of the steel. Thus a 45% NaCN bath will not affect the surface of a eutectoid steel, and a 15% bath will not affect a steel containing 0·3% carbon. In the case of the 0·9% C. steel, the temperature of treatment would be 760/780° C. The 0·3% C., 3·0% Ni steel would be treated at 850° C. The times of treatment would be normal. If, however, the time of treatment is unduly prolonged, or the temperature raised above the correct figure, decarburisation may occur. Again, if the bath temperature is reduced below 700° C., a nitride case will be conferred. This article is too short to deal with all the aspects of nitriding in cyanide baths, and only a brief paragraph on this subject is appended.

The same is true of non-cyanide melts with the exception that these will not carburise, but only tend to decarburise. Baths free from cyanide should not be used above 850° C., or for long treatment if decarburisation is to be avoided. It is possible to harden eutectoid steel from a cyanide-free bath, with no practical decarburisation. If the bath is properly compounded, kept fresh and the steel immersed for the minimum time, satisfactory hardness will be obtained. If, however, unsuitable constituents are used to make up the bath, or unnecessarily high temperatures are employed, of if the time of treatment is unduly prolonged, decarburisation may be expected. This brings up the question of composition, and introduces a difficulty. There are many heat-treatment salts on the market, all of them proprietary and a few patented. It would be inadvisable to disclose such analyses. The following remarks will, therefore, be general.

As mentioned above, non-cyanide salts may be divided into low- and high-temperature melts. The former consists of mixtures of nitrates and nitrites, and the latter of chlorides, sometimes containing carbonates. The nitrate-nitrite bath will be left alone meantime.

The temperature range of the chloride and chloride-carbonate baths is from 450° to 900° C. (There are also salts usable between 950° C. and 1,400° C.) The aim of the compounder is to obtain a useful range of temperature, and this is normally between 550° and 850° C. The chlorides of sodium, potassium and barium are the usual constituents, but $CaCl_2$ is often added to reduce the melting point. Sodium carbonate is also used on account of its cheapness. These two latter materials should be used sparingly, or avoided altogether, since $CaCl_2$ is very deliquescent, and Na_2CO_3 is actively decarburising.

The choice of the suitable bath, or baths, for the heat-treatment of a particular steel, depends on the following considerations.

1. The cyanide bath may carburise, or decarburise, as explained above. Many heat-treating steels are now heated for hardening in the cyanide bath with the deliberate object of obtaining a case-hardening effect. Such steels are :

B.S.S. 5005/503	Oil hardening NiCr.
B.S.S. 5005/502	Air hardening NiCr.
1% Chromium	C. 0·3/0·4% : Cr. 0·75/1·1

Gears and press-tools have been proved to give greatly increased life, when treated in this way. For instance, gear-box gears for a heavy motor-lorry made from 5005/503, after hardening from the muffle, "picked-up" in less than 100 miles. When hardening from the cyanide bath, they did not pick up at all, but polished up on the pitch-line in use, and gave long service. A kit of press-tools, made in high-carbon manganese tool steel, required continual attention after muffle hardening. When hardened from cyanide, they lasted for years in constant use.

It sometimes happens, however, that even a slight case is not permissible. The cyanide bath is then best left alone.

2. If slight decarburisation is no detriment, the cyanide-free bath may be used. Provided the temperature of treatment is not above 850° C., and the time of immersion of the work does not exceed, say, 30 min., practically no precautions are needed. Parts amenable to such treatment are solid pins which are ground all over after hardening.

3. This is the difficult condition. Thin springs must not be decarburised, nor may they be case-hardened. There are also frequent jobs which are carburised and from which the case is afterwards machined in places.

If it is essential that these machined portions are free from any casehardening effect, after final hardening, a special technique must be adopted.

There are, of course, other devices, such as copper plating and differential tempering after final hardening. Incidentally stopping off by means of clay or proprietary compounds is useless in a salt bath. The salt removes the clay, and, in the case of cyanide baths, the bath itself is poisoned by the clay.

A useful and definite method is as follows :—

The parts are carburised in the cyanide bath, quenched in oil or water, or cooled in air, and then given the core-refining treatment, if required, followed by quenching. They are then treated at 650° C. in a chloride bath for about half an hour, and quenched in water to remove the salt. They are then machined. The final hardening from 780° C. must be done from a chloride bath. This will develop the full hardness of the carburised surfaces and leave the machined portions with the same degree of softness as the core.

It has already been explained that cyanide baths must be chemically controlled. Control is also necessary for cyanide-free baths, which must not decarburise. The instructions are simple. The bath must be regularly re-

TABLE IV.

Temperature Range.	Salt.	Uses.
150° C. to 550° C.	Nitrate-nitrite mixtures and nitrates	Tempering of steel. Heat-treatment of aluminium alloys. Austempering.
480° C. to 600° C.	NaCN—KCN	Nitriding.
550° C. to 950° C.	NaCN—Na_2CO_3	Nitriding: Casehardening: Heat-treatment of steel.
520° C. to 900° C.	Chlorides (sometimes containing carbonates)	General heat-treatment of steel. Preheating, quenching and secondary hardening of high-speed steel.
1,000 C. to 1,400 C.	Special chloride baths	Harending of high-speed steel.

N.B.—Cyanides and nitrates or nitrites, must not be mixed. It is permissible, however, to quench steel from a bath containing not more than 10% NaCN into molten nitrates.

Cyanides, chlorides and carbonates can be mixed with safety.

Chlorides, carbonates, nitrites and nitrates are also compatible.

generated with fresh salt. These baths take up atmospheric oxygen and slowly become oxidising, and the effect is intensified by increase of temperature. This objectionable characteristic may be controlled by discarding a portion of the bath daily, and making up with new salt. If the throughput of work is sufficient to cause a large dragout of salt, it may not be necessary to discard any of the melt before regenerating. Another point to bear in mind is that working at temperatures above 850° C. accelerates the decarburising effect.

The foregoing has dealt with the better-known uses of salt baths in the ferrous industry. There are other applications, some of which are developing rapidly and others more slowly. Possibly the most interesting are the advances made in connection with the treatment of high-speed steel. A chloride base salt—also proprietary—is now available, which can justly claim to harden high-speed steel without scale and substantially without decarburisation. The cobalt steels still resist this salt, and some users complain of a soft skin, some 0·0005 in. thick. This is admitted. But this very superficial soft zone can be restored to full hardness by treatment in the cyanide bath at between 560° C. and 620° C. This is a comparatively new process, and must be used with discretion. This brings us to a consideration of the nitriding effect of the cyanide bath.

As has been written elsewhere, the nitriding effect of the cyanide bath is the greater the lower the temperature and the lower the NaCN content of the bath. Nitriding, whether done by ammonia or cyanide, is too large a subject for detailed consideration here. The use of cyanide baths for this purpose is comparatively new, but has already attracted considerable attention both in this country and in America.

Eutectic mixtures of potassium and sodium cyanide melt at 480° C., the melting point sinking, in use, to 450° C., and can nitride suitable alloy steels between this temperature and 760° C. The simple sodium-cyanide bath can be used down to 550° C. for the nitriding of high-speed steel.

Another important development is the process described as austempering. This consists essentially in quenching from the hardening temperature into molten salt held at temperatures between 230° C. and 500° C. Certain shapes and sizes of carbon steels, when treated in this way, give physical properties which are superior to those obtained by hardening and tempering. The process also gives better control than hardening and tempering, and consisting, as it does, of only one operation, is cheaper than the old-fashioned method.

The only other important industrial use of the salt bath is the treatment of aluminium alloys in molten nitrates. Again, this is a large subject, and is only mentioned here for the sake of completeness. Such baths should not be used above 550° C., on account of the danger of explosions, which are reported to have had fatal results.

No process is perfect. Although salt-bath methods of carburising and heat-treatment are possibly the most versatile of all, they have their drawbacks. Let us consider the safety aspect. The poisonous nature of cyanide is a stumbling block to the uninitiated. But the fumes from molten cyanide are definitely non-poisonous, as can be proved did space permit. The danger of the salt bath is that of burns caused by the introduction of wet work. It can never be over-emphasised that water, abruptly submerged in molten salt—or lead—will throw out, explosively, the contents of the pot. This danger is common to all molten baths, be they salt or metal.

There is another important characteristic of the salt bath which must be borne in mind by the metallurgist. The rate of heating is known to be high. Rapid heating tends to elevate the critical point of steel. For this reason it is well to work at the higher limit of the metal and the treatment. An arbitrary rule is to work 20° C. higher than in the dry, or muffle, furnace. Instead of hardening from 760° C., harden from 780° C.

Finally, Table IV of all the baths in common use must be interesting.

Corrosion of Thallium by Acids and Water

THALLIUM is a white metal rather softer than lead with a melting point of 303° C., a density of 11·8, and an atomic weight of 204·4. In the air it is rapidly oxidised and acquires a grey coating of oxide. Although of minor importance in metallurgy, studies of the corrosion of thallium are valuable in that they may throw light upon corrosion phenomena in general.

The field was first explored about a decade ago by Centnerszwer[*], who compared the speed of dissolution of thallium sheets when dipped in nitric, hydrochloric and sulphuric acids. Under the conditions of these experiments the rates of solution in acids of normal concentration at 25° C. expressed as mg. cm.^{2}/min. were:

n Nitrid acid	1·85
n Sulphuric acid	0·0049
n Hydrochloric acid	0·0023

The much more intense action of the nitric acid also held good over a wide range of other concentrations, and the author made no attempt to account for this marked difference in corrosive power.

In the more recent work of Plank and Urmanczy[†] at the Budapest Technical High School, pure thallium was first prepared from doubly recrystallised thallium sulphate by the electrolytic method of Vanino.[‡] After fusion under potassium cyanide in a porcelain crucible, the mass was rolled out into sheets of 4 mm. thickness. The rate of corrosion in mineral acids in contact with the air was studied over a wide range of concentrations. The above-noted more intensive action of nitric acid was partly explained by the fact that corrosion in hydrochloric and sulphuric acid is at first intensified with increasing acidic concentration, but soon reaches a maximum (at 0·01 n), and then declines; in nitric acid, however, no such maximum was observed. Thallium foil dissolved in 0·01 n hydrochloric acid at the rate of 0·0556 mg. cm.^{2}/min., and in 0·1 n acid at the rate of only 0·02 mg. cm.^{2}/min. In nitric acid the corrosion intensity increased linearly over the normality range of 0·01 n to 0·5 n. Formulae developed by the authors to express the behaviour on corrosion gave results closely agreeing with the experimentally determined figures.

Effect of water.—The rate of corrosion of thallium metal in water was directly proportional to the dissolved oxygen content. Oxygen-free water saturated with hydrogen did not attack thallium.

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[*] *Zeitschr. Elektrochem.*, 37, 603 (1931).

[†] *Korr. and Metallschutz*, Jan.–Feb., 1940, 33–8.

[‡] *Handbuch der präparativen Chemie*, **1**, 396 (1913).

Annealing and Drawing Characteristics of Oxygen-Free Copper

The results of an investigation are given which had for its object the determination of the annealing and drawing characteristics of an oxygen-free high-conductivity copper containing phosphorus.

SINCE the investigations of Webster, Christie, and Pratt[1] on the comparative properties of tough-pitch, electrolytic tough-pitch, phosphorised, and oxygen-free high-conductivity electrolytic (OFHC) copper, steps have been taken to produce a copper which would combine the desirable characteristics of OFHC copper with those of phosphorised copper. Such a copper has an immunity to embrittlement when heated in a reducing atmosphere, and a high reduction of area and elongation, is free scaling, and has a higher softening temperature than OFHC copper. It contains 0·015 to 0·025% of phosphorus, and can be produced from electrolytic copper cathodes under the same precise control of atmosphere and temperature as used in the production of OFHC copper. To determine the annealing and drawing properties of this copper and to compare such properties with those of other types of copper an investigation has been carried out recently by S. Rolle and H. M. Schleicher.[2]

Tests were made both on rods and on tubing fabricated in the usual manner. The object of testing tubing was on account of phosphorised copper, being almost exclusively used for tubing, and it being considered desirable to determine the effect of the form of the copper under test. Three kinds of copper were investigated—phosphorised copper, oxygen-free high-conductivity copper (OFHC) and oxygen-free high-conductivity copper containing phosphorus (OFHC + P). Phosphorised copper or phosphorus deoxidised copper was made from electrolytic copper to which phosphorus was added in sufficient quantity to deoxidise the metal and leave a residuum of about 0·020% phosphorus. The oxygen-free high conductivity copper was produced by a patented process from electrolytic copper cathodes and contained no residual deoxidant. Its electrical conductivity was high, due to the impurities being kept below certain limits. The third oxygen-free copper was prepared by adding enough phosphorus to molten OFHC copper to obtain a specified content of approximately 0·015% and allowing none for deoxidation. All the coppers were fully analysed by chemical and spectographic methods and none of the impurities present were found to be in abnormal amounts.

For the testing of rod samples, billets from each of the coppers were heated to about 825° C., hot-rolled to 0·81 in. diameter rods, annealed at 600° C. for 2 hours, pickled, and cold-drawn in two stages to 0·5 in. diameter rods, a total reduction of 62·5%. For annealing tests, the 0·8 in. rods from each copper were then annealed for 1 hour at 190°, 220°, 250°, 300°, 400°, 500°, 600°, and 700° C., and for drawing tests, the 0·5 in. diameter rods from each copper were cut into 3 ft. lengths, annealed at 500° C., pickled, and drawn to sizes each diminishing by about 0·03 in. to 0·158 in., or 90% total reduction. The tensile strength, elongation, reduction of area, and grain size were then determined on all the annealed and drawn rods.

The tube samples were prepared by piercing billets from each copper in a Mannesmann machine to shells 2·5 in. O.D. by 0·25 in. wall. One-half of each shell was drawn without previous annealing to 0·875 in. O.D. by 0·065 in. wall, a reduction of 90·5%. The other half of each shell was drawn without previous annealing to 1·5 in. O.D. by 0·100, then annealed at 500° C. for 2 hours and redrawn without annealing to 0·875 O.D. by 0·065 in. Lengths of 12 in. were cut from each piece of 0·875 O.D. by 0·065 in wall tubing made from both halves of the shells and annealed at 250°, 275°, 300°, 325°, 350°, 375°, and 400° C. Tensile tests were then made on each annealed tube and elongations measured on 2 in. length. Rockwell hardness tests were also made on the concave (inside) surface of each tube.

The results of the various annealing tests showed that in the rod samples reduced by 62·5% the two phosphorised coppers behaved similarly and softened at 400° C. with all the impurities and also about 0·013% phosphorus in solid solution, while the OFHC copper, with practically all the impurities in solution, softened about 350° C. Marked crystal growth also started at a higher temperature in this copper than in the other two coppers. In the tube samples 62·5% hard, the three coppers behaved somewhat similar to their behaviour in the rod samples, the two phosphorised coppers resisting softening at 50° C. higher than the OFHC copper. The relative positions of the curves for the three coppers in tube samples, 90·5% hard, were similar to those of the tubes 62·5% hard. The harder tubing of the OFHC copper, however, softened at a slightly lower temperature than the softer tubing, but there was no difference with the phosphorised coppers.

The grain size versus temperature curve for OFHC copper showed the grain size to increase markedly over 625° C. In phosphorised copper and in OFHC + P copper grain growth began at lower temperatures than in OFHC copper, the break occurring at about 600° C. At this temperature there was a marked difference between the size of the grains of this copper of about 0·027 mm. and those of the two phosphorised coppers which were 2½ times as large. Full growth was attained in all three kinds of copper at 700° C. As regards the effect of cold-drawing, it was found that the reduction of area data for the two OFHC coppers was the same throughout the range of the annealing temperatures, and was decidedly higher than for the regular phosphorised copper. It was also noted that the OFHC copper had a tendency to remain softer in the higher range of reduction.

In general oxygen-free high conductivity copper softened at a lower temperature than similar copper to which 0·015% of phosphorus had been added or to phosphorus deoxidised copper, and all three coppers softened at a much higher temperature than electrolytic tough-pitch copper. The cold-drawing characteristics of the two oxygen-free coppers were closely similar, which seemed to indicate that all the phosphorus in the phosphorised copper was not in solid solution, some of it being probably in oxidised form. The approximate softening temperatures of the various coppers tested were 350°, 400°, 450° for the oxygen-free high-conductivity copper, for the same copper with phosphorus added, and for the phosphorus deoxidised copper respectively, and these temperatures were those at which the three coppers became dead soft or at which their tensile strengths were at a minimum. The annealing characteristics of the three coppers were not appreciably affected by the form in which the copper was tested, as increasing the reduction by cold-drawing from 62·5 to 90·5% had but little effect on the annealing characteristics of any of the coppers investigated. The only insignificant difference in the results obtained in the investigation from those obtained in previous investigations was in the grain growth of the oxygen-free high conductivity copper which occurred at a higher temperature. In this respect it is of interest to note that in determining grain size it was essential to avoid the zone of oxygen penetration which occurs when oxygen-free high conductivity copper is heated in air.

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[1] Trans. A.I.M.E., Inst. of Metals Div. 1927 and 1933, pp. 233 and 166.

[2] *Metals and Alloys*, 1940, Vol. II, No. 3, pp. 82–87.

Porous Anti-Friction Cast Iron made from Powder

M. Yu. Ballshin and N. G. Korolenko

During recent years much research has been devoted to powder metallurgy, and the results have led to considerable development. Some of this work has been concerned with porous bearings, and in this abridged translation of a report by the authors is given a description of a research on the subject carried out at the laboratory for powder metallurgy at the Central Scientific Research Institute for Machine Construction.*

THE advantages associated with porous bearings produced by powder metallurgy are now well known. The anti-frictional properties of these materials have enabled a greater variety of metals to be used for bearings, the recent tendency being for iron-base bearing alloys to replace non-ferrous alloys for this purpose. The chief disadvantage of iron-graphite bearing materials produced from powders is the, at present, comparatively high cost of the original iron powder and the necessity for sintering them in a reducing atmosphere. The work of the authors was therefore directed towards developing methods for making use of powders produced from cast iron, by crushing this material either in the as-cast state or in the form of turnings.

The use of cast iron has the advantages of low cost and the lower tendency of the cast iron powder to oxidise. When use is made of specially cast material, the cost of the powder is less than that of the iron powder obtained by reduction (electrolytic or carbonyl iron powder). If use is made of scrap material (filings or turnings), the cost of the powder may even be less than that of cast iron. The presence in the powders of uniformly distributed carbon enables them to be sintered without the use of a special reducing atmosphere, as, for example, in closed boxes. The presence of a definite amount of silicon and the method of production used allow a control of the final structure of the bearings.

Choice of Raw Materials

The choice of the raw material has to be based on the chemical composition and physical nature of the original cast iron which determine the crushability, compressibility and the sintering of the powders, as well as the properties of the finished products. The silicon content of the cast iron used should not exceed 1·7%, contents of 0·8–1·3% being preferable, as the silicon content reduces the strength and makes pressing more difficult owing to its effect of increasing the elastic properties and reducing the ductility of the particles. On the other hand, too low a silicon content slows down the graphitisation. The sulphur, phosphorus and manganese contents should preferably be as low as possible, as they interfere with sintering and also reduce the transcrystalline strength of the porous bearings. The effect of the carbon content in white cast iron on the crushability has not yet been fully investigated. In grey cast iron an increase in carbon content (both the total and free), facilitates crushing, particularly if the distribution of the graphite is favourable. On the other hand, a high graphite content results in the particles becoming coated with graphite during grinding, and this weakens the cohesion between the particles and renders their compression more difficult. Excess graphite can, however, be readily removed by the use of the special annealing treatment which the authors have developed and to which reference will be made below.

The physical state of the original cast iron is of no less importance than the chemical composition. The use of white cast iron has the advantages, as compared with grey and malleable cast iron, that the particles during crushing do not become flattened out by the forging action, and their surface roughness is not reduced. As a result of this, annealed white cast iron powder can be more readily compressed and gives rise to better mechanical properties in the finished products than grey cast iron of the same chemical composition. On the other hand, the use of grey and, to a certain extent, malleable cast iron is more economical, as it is possible to make use of scrap, turnings, etc., which are only rarely available in the case of white cast iron. It is possible, however, that in the future improved methods of grinding, such as the use of eddy mills, will enable one to reduce the unfavourable flattening of the particles of soft cast irons to a minimum.

If white cast iron is used it generally has to be specially cast in the form of thin rods, plates, etc. As regards chemical composition, white cast iron containing 2·5–3·5% C, 0·8–1·7% Si, up to 0·3% P, up to 0·8% Mn, and 0·03–0·08% S, is most suitable. Grey cast iron of a similar composition can be used. Special additions may be made to the powdered charge, such as, for example, iron powder, iron oxide, graphite, copper, zinc, etc., with the object of improving the compressibility, controlling the composition of the charge with respect to graphite, silicon, etc., controlling the final structure of the products, or to lower the sintering temperature by the addition of low melting point non-ferrous metals.

Grinding of the Cast Iron

For grinding it is desirable to start with material in a coarsely sub-divided state. The use of turnings, in which the cohesion of the metal has already been appreciably reduced, is particularly favourable. The crushability of the material is influenced by its brittleness, which may be due to inter- and intra-crystalline brittleness of constituents, such as, for example, cementite in white cast iron and the presence of layers of graphite in grey and malleable cast iron. While white cast iron can be readily crushed in ball mills, the softer grey cast iron and malleable cast iron particles tend to become flattened out, and this leads to low strength in the compacts.

As has been mentioned above, however, it may be possible to avoid this by the use of eddy mills. The grinding of grey and malleable cast irons is further complicated by the more rapid breaking up of the graphite which gives rise to a finer powder than the metallic constituents, the fine graphite powder then coating the particles. This may give rise to defects in the compacts and for the sintered materials. In practice, it has been found that grinding to 150-200 mesh is sufficient. In many cases, particularly for grey and malleable cast irons, it is preferable to reduce only some 20–30% of the material to this degree of sub-division, the coarser fractions then being separated and used for other purposes.

For hot pressing, coarser powder of 20–30% mesh can be used. The coarser powders may also be used for cold pressing, provided special additions for the purpose of improving the compressibility are made.

Preliminary Annealing

The process of preliminary annealing was introduced as a necessary operation for removing the difficulties which arise during compressing and partly also during sintering of compacts made from unannealed cast iron powders. The compacts made from unannealed white, grey or malleable cast-iron powders have a low strength and exhibit an appreciable tendency to crack. The poor compressibility of unannealed white cast iron powders is due to the low ductility and deformability of the hard structural constituents, cementite and to a lesser extent pearlite, while the poor compressibility of grey and malleable cast iron powders is due, as has been mentioned above, to the flat shape of the particles, the coating of graphite on their surface, and the work hardening imparted to them during grinding.

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* *Vestnik Metallopromyshlennosti*, March, 1939, pp. 34–41.

The special additions which have been recommended by various authors to improve compressibility and which generally consist of non-ferrous metal powders, cannot be considered as a satisfactory solution of the difficulty.

The annealing treatment which has been developed improves the compressibility and the mechanical strength of the compacts for the following reasons :—

(1) Graphitisation during annealing, as a result of which the cementite and pearlite are changed to the more ductile ferrite, which is particularly important in the case of white cast iron.

(2) Elimination of the finely dispersed graphite when annealing in an oxidising atmosphere, in hydrogen or after the addition of oxides.

(3) Removal of the work hardening. This is of particular benefit for grey and malleable cast iron powders.

(4) Some increase in the roughness of the surface of the particles.

(5) Reduction of oxide films when annealing in a reducing atmosphere.

Annealing is best carried out above the pearlite transformation point—i.e., between 750° and 900° C. The time required is determined by the degree of graphitisation required, and the rate of elimination of the graphite. For fuller graphitisation the rate of annealing should be as slow as possible. The best way of carrying out the annealing treatment is in closed boxes with a protective packing (graphite, crushed coal, etc.). In cases where the annealing treatment is carried out after the addition of iron oxide, the use of a rotary furnace or some means of stirring the powder is advisable.

It must be pointed out that graphitisation of the cast iron products is much more rapid than when annealing massive cast iron, owing to the greater ease with which changes in volume take place and the large free surface of the powder. Thus, when annealing a white cast iron powder with 2·66% total C, 2·51% combined C, 1·67% Si, 0·42% Mn, 0·034% Si, 0·064% P, graphitisation was complete after 2 hours, whereas a total time of 10·3 hours has been quoted for complete graphitisation of massive cast iron of the same composition. In addition to improving the compressibility, annealing also has a beneficial effect on the sintering process by shortening the sintering time required and improving the properties of the finished products.

Mixing

Mixing has, of course, for its object the production of a uniform powdered material, and in this connection particular care should be taken when mixing powders obtained from different grades of cast iron. In many instances, the addition of graphite, iron powder, or other materials may be necessary. Mixing is best conducted in drums rotated about an eccentric axis.

Pressing

As in all powder metallurgical processes, pressing is of very considerable importance, and must lead to compacts having sufficiently high mechanical properties, since poor compacts will not yield satisfactory material after sintering. As has been mentioned above, difficulties in pressing have led to the development of the annealing treatment for the cast iron powders. Compacts obtained from annealed cast iron powder may have, depending on the requirements, from 20–20% porosity. The pressures used vary, depending on the size of the compacts and the porosity required, from 2,000 to 5,000 kilog./cm.²

Sintering

The optimum sintering temperature for cast iron powder is about 1,100° C. Higher temperatures cannot be used as melting of localised eutectic regions may occur at 1,145° C. If the powder has been given a preliminary annealing treatment, the sintering time is considerably shortened. The time at the maximum temperature depends mainly on considerations of a uniform temperature being obtained throughout the compacts, and may vary from 30 mins. to 2 hours. Cooling should preferably be as slow as possible.

Sizing

The sintered products may be sized either by machining or by repressing. The porous sintered cast iron can be

TABLE I. WEAR OF POROUS CAST IRON BEARINGS.

No. of Specimen.	Composition of Powder Mix.	Wear of Porous Cast Iron Specimens, g./cm.² km.	Wear of Steel Roller, g./cm.²/km.	Brinell Hardness (Load 187·5 kilog., 5 mm. Ball).	Structure.
1	80% white cast iron + 20% fine iron powder.	0·00037	0·000023	24·9	Ferrite + graphite + 20–30% pearlite.
2	85% white cast iron + ...	0·00067	0·000015	25·8	do.
3	15% fine iron powder	0·00022	0·000013	—	
4	60% grey cast iron + 40% fine iron powder.	0·0002	0·00008	27·9	do.
5	75% grey cast iron + 25% fine iron powder.	0·00077	0·00018	34·2	do.
6	80% grey cast iron + ...	0·009	0·00005	39·0	do.
7	20% fine iron powder	0·00195	0·00003	—	
8	77·5% cast iron + ...	0·00013	0·000021	17·2	Ferrite +
9	2·5% graphite + 20% fine iron powder.	0·000054	0·000078	18·1	Graphite.
10	97% cast iron + ...	0·00627	0·000042	—	do.
11	3% graphite	0·00013	0·000018	23·9	
12	97·5% cast iron + 2·5% graphite	0·00027	0·000019	23·4	do.
13	97% cast iron + 3% graphite......	Specimen increased in weight by 0·0186 owing to soaking up of oil.	0·00026	21·3	do.

NOTES.

CONDITIONS OF SINTERING.

The specimens were sintered in boxes filled with a mixture of 70% sand and 30% graphite by heating to 1,110° C., holding for 5 hours and cooling in the furnace.

TEST CONDITIONS.

Specimens 1 to 12.—

(1) Tests were carried out on the Amsler wear-testing machine without additional lubrication under a load of 30 kilog. cm.²

(2) Wearing material was quenched steel with a hardness of 50 Rockwell C.

(3) Wear was determined by weighing to four places of decimals.

Specimen 13.

The test was carried out under a load of 75 kilogs. cm.², and lubrication by motor-car oil was provided.

readily machined at the usual speeds, but sizing is more economically effected by repressing. For this purpose special repressing dies on eccentric presses and pressures from 500 to 2,000 kilogs./cm.^{2} are used.

In the following section the authors summarise the pros and cons of hot pressing, as applied to the production of parts from powdered metals. No reference is, however, made to the application of this process to cast iron powders.

Results of Preliminary Tests of the Properties of Porous Cast Iron

The tests of the bearing and mechanical properties of porous cast iron have not yet been completed, but the available preliminary results lead one to suppose that porous cast iron presents a considerable interest as a new anti-frictional material, and merits a closer study. As compared with cast anti-frictional cast iron, the porous material has a number of advantages. Owing to the presence of porosity, a film of lubricant which makes dry friction impossible, is always present. It is possible to lubricate these bearings through the pores, the lubricant diffusing to the surface of the shaft. The presence of specially added graphite of suitable particle shape and uniformly distributed, constitutes another advantage of the material. Owing to its porosity, the material can be deformed, not only as a result of a flow of material, but by changes in the shape of the pores. In view of this, the porous material is much easier to run in than massive cast iron. The hardness of the sintered material can be varied at will from 20 to 80 Brinell, and this low hardness enables it to be used with unhardened shafts. The cross-breaking strength of porous cast iron is about 17–18 kilogs./mm.^{2} The strength of the material can be increased some 25–30% by the addition of about 10% of copper. Thus, for example, bushings 25 mm. long, 18·4 mm. outside diameter, and 12·4 mm. inside diameter had a resistance to compression in a radial direction of about 300 kg. per bushing, while this was raised to about 400 kilogs. by the addition of copper.

As will be seen from Table I, the wear of porous cast iron bearings is slight, and varies from 0·00005 to 0·002 grm./cm^2/km. There are, however, reasons to believe that part of this represents the loss of oil from the pores. This assumption is supported by the fact that specimen No. 13 actually showed an increase in weight by absorbing the lubricant which was provided. All the other specimens were tested without additional lubrication, and were therefore liable to lose some of their absorbed oil. The wear of the steel roller is very slight, and varies from 0·000014 to 0·00026 grm./cm.^{2}/kilog. The coefficient of friction in tests on the Amsler machine varied from 0·04–0·06. This somewhat high figure for the coefficient of friction is probably due to the absence of continuous lubrication in the tests and also to incomplete running in.

Heat-Transfer in the Flow of Gas Through a Bed of Solid Particles

An investigation is summarised in which the problem of the transfer of heat from a gas to a bed of solid particles is approached from first principles, in order to relate the heat transfer to the shape and dimensions of the bed and particles, the physical characteristics of the material, the velocity and temperature of the gas, etc.

IN designing industrial plant for the transfer of heat from a gas to a bed of solid particles, the lack of fundamental information has been a great handicap. The general problem is to relate the heat transfer to the shape and dimensions of the bed and particles, the physical characteristics of the material of the particles, the velocity and temperatures of the gas, etc.

The investigation presented in this paper by O. A. Saunders and Dr. H. Ford* approaches the problem from first principles, endeavouring to correlate the effects of the different variables. Theoretical considerations show that the heat transfer is governed by certain dimensionless groups of variables, just as the nature of fluid motion is governed by the well-known group of variables

$$\frac{\text{Velocity} \times \text{Linear size}}{\text{Kinematic viscosity}}$$

known as the Reynolds number. But since certain assumptions and approximations have to be made in the theory, experiments with beds of spheres were made to test out the dimensionless groups arrived at.

The heat has to be transferred in two stages: first by convection from the gas to the surface of the particles, and secondly by conduction to the interior of the particles. As would be expected, the theory shows that for particles of small size or large conductivity, the heat transfer should be practically independent of conductivity; but the limits within which this is true can best be found experimentally. So far, however, the point at which conductivity becomes important has not been reached.

It is shown theoretically that the heat transfer is governed by the dimensionless groups $V\tau c'/lc$ and Vlc'/k, and by the shape of the bed and particles (V = mean linear velocity of the gas entering the bed; τ = time; c' = specific heat of unit volume of gas at constant pressure; l = characteristic linear dimension; c = specific heat of unit volume of material of the particles; k = conductivity of the particles); also that Vlc'/k may be neglected if it is small enough, that is to say, if the size, l, of the particles is small enough or their conductivity, k, large enough, for the effects of temperature differences in their interiors to be neglected; in such cases the thermal conductivity of the particles is of no importance. Once the validity of these groups has been checked experimentally, the results can be applied to the whole possible range of materials, provided that their physical constants are known.

Experiments to test out the theory are described, in which hot air was passed through beds of various depths of steel, lead or glass spheres of diameter up to 0.25 in. It was found that the results for different sizes, velocities and materials could be correlated with $V\tau c'/lc$, indicating that the effects of temperature differences within the particles were negligible in the experiments.

Curves are given for calculating the variation of gas temperature through a given bed at any given moment. It is shown, for example, that the time taken to attain a given temperature at a given depth of bed is directly proportional to the specific heat and density of the particles, inversely proportional to the gas velocity, and only slightly affected by changes of particle size. Curves are also given for the heat transfer.

The highest value of Vlc'/k in the experiments was about 4, corresponding to diameters of 0·25 in. and 11 in. for glass and steel, respectively, at an air speed of 2 ft per sec. The results are, therefore, applicable up to these sizes; how far they are valid for larger sizes remains to be found by further experiments, but rough calculations show that the errors in using them up to sizes two or three times those quoted are probably only a few per cent.

Only part of the ground has been covered in the present experiments, and the results, therefore, are of limited application, but it is hoped that the methods developed will in due course be extended to cover the whole field, and eventually include the more complicated conditions found in industrial plant.

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*Iron and Steel Institute. Reprint, May, 1940. 26 pp.

Correspondence

Assistance with Technical Problems

The Editor, Metallurgia.

Dear Sir,

To-day when the industries of the country are concentrating on the rapid increase in the production of war material new problems are bound to arise.

The International Tin Research and Development Council would like to emphasise that it has accumulated much experience, particularly since the war began, on a wide range of processes in which tin is directly or indirectly concerned, and that this experience is available to your readers—without charge. These processes include :—

- Grease-tinning and hot-tinning.
- Soldering.
- Bearings and bearing materials.
- Bronze.
- Electro-tinning.
- Fusible alloys, particularly for rapid die and punch mounting, tube bending, etc.

Advice can sometimes be given by correspondence, but, as in many cases personal contact is much more effective, the Council is prepared to send members of its staff to give assistance and advice at the works directly concerned.

Yours faithfully,
W. H. Tait,
Technical Developments Manager.

International Tin Research and
Development Council,
Fraser Road, Greenford,
Middlesex.

May 27, 1940.

[Readers will appreciate that this Council was formed primarily to deal with problems directly and indirectly associated with the many applications of tin, and a competent staff has been engaged for many years in their solution. Obviously members of this staff are specialists and can do much to help in overcoming difficulties which may be experienced in the processes mentioned. There should be no hesitation, therefore, in taking advantage of this offer when expert assistance is desirable.—*Editor*.]

Inexpensive Method of Detecting Flaws in Castings

The Editor, Metallurgia.

Dear Sir,

An inexpensive method of detecting hidden flaws in ferrous and non-ferrous castings has been suggested to me and I should be glad if you would say whether any of your readers have knowledge and experience of the procedure, which is as follows :—

The castings are to be freed from sand, placed in boiling water for 10 minutes, taken out and placed in a solution comprising equal parts of machine oil, turpentine and paraffin, and left to soak for half an hour. They are then taken out, washed in boiling soda and water to clean, whitewashed, placed in a hot oven to dry for a few minutes, after which any flaws show up a yellow vein on a white surface, and such flaws are detectable anywhere in the metal.

Yours faithfully,
R. Bryden.

Roundhay, Leeds, 8.
May 23, 1940.

[The procedure suggested is an old form of non-destructive test for determining surface flaws in castings, for which there were many variations. If a crack in an iron or steel casting was suspected it was fairly common practice at one time to clean the surface with a wire brush and apply a mixture of heavy oil and paraffin. After being allowed to remain half an hour or so the oil was removed from the surface and any cracks present could be seen. This method gives no indication of the depth of a crack, nor does it show internal flaws, and other methods are now more commonly used.—*Editor*.]

Notes on the Forming of Aircraft Structural Components

The bending of light-alloy sections to the profiles required for modern aircraft construction is now becoming a highly developed technique. As in the case of the forming of all specialised alloys, however, it is essential that the procedure laid down by the producers of the materials should be rigidly adhered to. The following notes furnish an interesting example of such a recommended procedure.

An extruded T-section 2 in. × 2 in. × $\frac{1}{4}$ in. of an aluminium alloy NA. 26.S, produced by the Northern Aluminium Company to meet DTD. 364, was required to be bent into aerofoil profile for use as a wing member in a large aircraft. In formulating the most efficient technique for the purpose, strain calculations were taken out, and it was found that the maximum strain involved, a compressive one at the foot of the stalk, was of negligible amount—actually 0·84%. Thus, the alloy mentioned, in the ductile solution-treated condition could be recommended as being thoroughly suitable for the purpose. In this connection, it is important to note that the material can be supplied from the maker in the solution-treated condition, thus avoiding complications of heat-treatment in a fabricating factory.

Initially, the forming of the section to profile was achieved by rolling in a manner such that all deforming pressure was applied to the undersides of the flanges only. Since it was felt, however, that this entailed some risk of setting up internal stresses, the practice was recommended of applying pressure, by means of the centre roll, on the foot of the stalk as well as on the underside of the flanges.

Following the rolling process, the material was subjected to artificial ageing, this consisting of heating to a temperature of 170° C. (± 5° C.) for a period of 10 to 12 hours. By this means, optimum mechanical properties could be realised in the section without risk of distortion when in the formed condition. Details of the mechanical properties, together with the specified limits of composition, are given in the accompanying tables.

Chemical Composition Specified in DTD.364

Cu.	Mn.	Mg.	Si.	Fe.	Al.
3·0–4·5%	1·2% max.	1·0% max.	1·0% max.	1·0% max.	Remdr.

Minimum Mechanical Properties Guaranteed for NA.26S to DTD. 364 and Average Figures Obtained.

	Solution Treated.	Solution treated and Aged.	
	Average.	Min.	Average.
Proof stress (0·1%), tons/sq. in.	23	26	28
Ultimate tensile strength, tons/sq. in.	30	30	32
Elongation (per cent.)	16	8	10

The example is of value in illustrating the desirability of collaboration between producers and consumers of aluminium alloys. By providing a material which can be supplied in the solution-treated condition, the producer relieves the aircraft constructor from the necessity of undertaking solution heat-treatment and the subsequent straightening which is usually involved, an economy of skilled labour which is of particular importance at the present time.

Also, by accepting advice from the makers of the material, who, after all, possess the fullest knowledge concerning its mechanical characteristics, the user ensures that he is adopting the simplest and most economical technique possible if failures during construction and in ultimate service are to be prevented.

Personal

Mr. J. E. Spear, previously Sales Manager, Engineering Division of British Timken Ltd., has now been placed in charge of a new department which will be responsible for planning, control, and progressing of production. Before being appointed Engineering Division Sales Manager a year and a half ago, Mr. Spear was Railway Representative.

Nitriding Tool and Austenitic Steels

By D. W. Rudorff, A.A.I.E.E., F.R.S.A.

The reports of two recent investigations on the accelerated nitriding of tool steels and the nitriding of austenitic steels are reviewed. In one the combined application of two known methods of nitrification to various kinds of alloy steels is noteworthy. The second report is concerned with the determination of the increase in hardness of austenitic steels, and with the influence of the nitriding temperature upon the magnitude and hardness of the case produced.

SEVERAL investigations on various aspects of nitriding have been carried out recently by Russian metallurgists, and two of them are of considerable interest. One of these deals with the accelerated nitriding of tool steels, while the other is concerned with the nitriding of austenitic steels. The reports on these investigations present a number of interesting features, and the results obtained are reviewed in this article.

The first of these reports[1] is concerned with the problem of the development of a commercial process for the short-time nitriding of certain tool steels and also of an alloy steel of the so-called nitralloy type. The method of nitrification employed in this instance consists in the combination of the use of aniline or pyridine as catalyst, with the additional employment of a triplex temperature cycle. It need hardly be pointed out that in themselves these two possible means of process acceleration are not novel. However, the results of their combined application to various kinds of alloy steels are of more than usual interest, as well as of considerable informative value.

The composition of the steels investigated are as follows :—

TABLE I.

—		C.	Si.	Mn.	Al.	Cr.	W.	V.	Mo.
Nitralloy*	35XMYA....	0·31	0·21	0·42	1·38	1·64	—	—	0·73
Tool steel	3XB8	0·37	—	—	—	2·6	7·57	0·39	—
,,	X12M	1·61	0·45	0·32	—	12·5	—	—	0·75
,,	R	0·71	—	—	—	4·1	18·3	—	—
,,	I-172	1·08	1·58	0·45	—	11·47	—	2·44	—
,,	4XBC	0·37	—	—	—	1·0	2·2	—	—

*A Russian-made steel, not a product of Nitralloy, Ltd.

Prior to nitriding, samples of these materials, measuring 6 × 6 × 30 mm., were subjected to the heat-treatment given below :—

TABLE II.

—		Quenching in Oil.			Tempering in Air.		
		Temp. °C.	Time in Mins.	Brinell.	Temp. ° C.	Time in Hours.	Brinell.
Nitralloy*	35XMYA......	950	4	429	650	4	277
Tool steel	3XB8	1,100	4	461—514	650	4	352—415
,,	X12M	1,130	4	352—415	650	4	363—400
,,	R	1,280	2	653	570	1	653
,,	I-172	1,250	3	600	540	1	600
,,	4XBC	850	4	555	650	4	277

*A Russian-made steel, not a product of Nitralloy, Ltd.

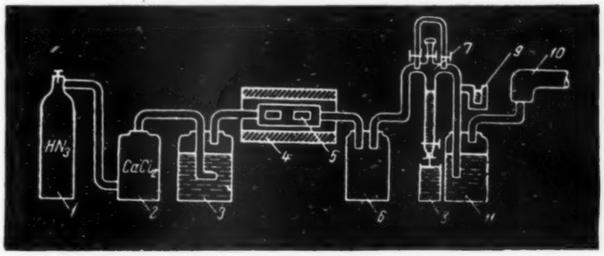

Fig. 1.—Flow diagram for nitriding with catalyst.

Nitriding of the samples was carried out according to the scheme outlined in Fig. 1. Here, ammonia gas, discharged from the bottle (1), is passed through a $CaCl_2$ dryer and, subsequently, bubbled through the aniline contained in the bottle (3), the depth of the aniline being 50—70 mm. From the aniline bottle the gas is passed into the nitriding container, consisting of a porcelain tube placed in the electric furnace (4). The dissociation of the ammonia gas is measured by means of the pipette (7), the degree of dissociation being maintained at approximately 15—30%. After termination of the nitriding process the gas flow is cut off when the temperature in the furnace has fallen to 180° C.

For the experimental nitriding of small manufactured parts a regular industrial furnace, as shown in Fig. 2, was used. Circulation of the gas in the furnace during nitriding was effected in the usual manner by a fan arranged in the lower part of the furnace. After nitriding, a complete examination of the test-pieces as to microstructure, hardness, depth of case, etc., was made, and an X-ray examination was also carried out. In addition to this the wear resistance of some of the tool steels was ascertained by a breakdown test. In the case of the high-speed steel R, test-pieces of 10 × 6 × 15 mm., inserted in special holders, were used.

Hardness testing was generally carried out by a Vickers tester, using a diamond pyramid under 10 kilog. load ; but in some cases a Herbert pendulum tester with a diamond ball of 1 mm. diameter was employed. The depth of the case was ascertained microscopically.

Altogether four different nitriding cycles at temperatures ranging from 500°—650° C., with the process time varying from 3—9 hours, were tried out. The various process conditions, as well as hardness and depth of the case obtained, are set forth in Table III given below.

None of the test-pieces showed case brittleness, and steel 3XB8 was therefore considered suitable as tool material where a considerable depth of case is required. As Table III shows, a small depth of case was obtained with steel X12M. Even the triplex cycle of $500 - \frac{570}{600} -$ 500, extended over 9 hours, produced a case depth of no more than 0·15 mm. This, however, was considered sufficient depth for gauges and measuring instruments in general where, in the opinion of the investigator, nitriding appears preferable to hardening, since nitriding causes a minimum of deformation and warping.

As Table III further shows, a high degree of hardness, combined with comparatively small depth of case, was obtained with steel R and with its less-expensive substitute, I-172. Although steel 4XBC showed a penetration of considerable depth no case could be produced, and this steel had therefore to be considered as unsuitable for nitriding.

In the opinion of the investigator the employment of the triplex cycle provides a satisfactory means of greatly reducing the length of time required with current nitriding methods, and this reduction is stated to be achieved

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[1] N. N. Liptshin and E. Glasuk, "Methods for the Accelerated Nitriding of Tool Steels and of Nitralloy 35XMYA," *Metallurg*, No. 6, 1939, pp. 47–53. (In Russian.)

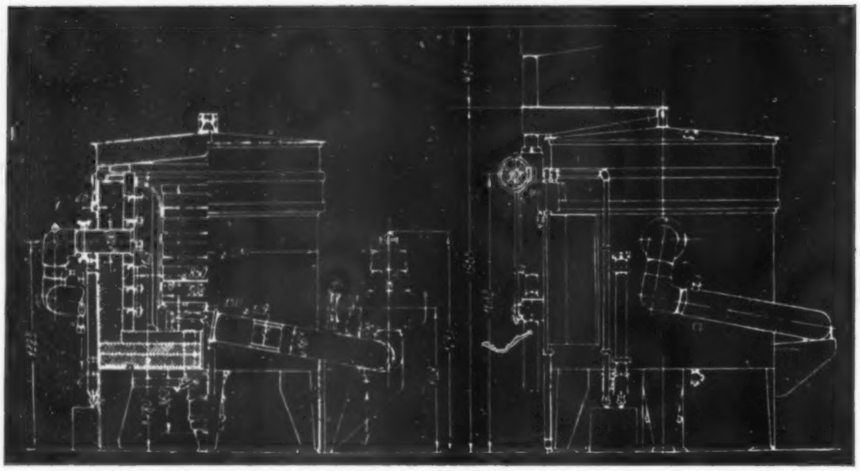

Fig. 2.—Russian nitriding furnace.

without sacrificing quality of the case from the aspects of brittleness and case depth.

The original report states also that the data obtained on material 35XMYA tally very satisfactorily with those reported by P. E. Mochalkin in his investigation of a duplex cycle.[2] As regards the nature of the triplex cycle, the first period in which 500° C. is maintained serves to create a small surface layer of nitride. In the second period, in which the temperature is increased from 570°—600° C., the growth of the nitrided layer by diffusion of the nitrogen into the material is accelerated. The third period, at the reduced temperature of 500° C., enables equalisation of the nitrogen in the surface film to take place, thereby securing greater hardness.

High-temperature nitriding at 650° C. is, of course, well known to give negative results, as nitriding at this temperature merely leads to increased penetration without an attending increase in hardness. It is, however, suggested that high-temperature nitriding may possibly find application to parts intended to operate at elevated temperatures, while no great demands with regard to hardness are made.

No appreciable difference in the process accelerating properties of aniline and pyridine was found to exist, and it is stated that these catalysts have also been tried out in Russia on a semi-commercial scale by using the furnace, shown in Fig. 2, without, however, resorting to cyclic temperature changes.[3]

A series of tests was made in order to ascertain the life of nitrided cutting tools ; but these tests proved to be far from conclusive. They are therefore not reviewed here. Of considerable interest, however, is the employment of steel 3XB8 as material for the dies of high-pressure die-casting machines for the die casting of brass, bronze, aluminium, etc. In machines of this type the dies are subjected to pressures as high as 1,800 lb. per sq. in., and more, with operating temperatures approximating 500° C. For this reason the dies must be made of hardened chrome-nickel, chrome-vanadium, or chromium-tungsten steel. Deformation of the frequently highly complicated dies during hardening often causes serious difficulties. Furthermore, the continuous change in working temperature, in combination with the high-operating pressure, often leads to the development of surface cracks making the die unfit for further use. It is very interesting to note that a series of tests under actual working conditions are said to have been carried out with the use of dies made of nitrided 3XB8 steel. This investigation is reported to have been made by Russian engineers at the works of a prominent Continental manufacturer of high-pressure die-casting machines. The nitrided dies were found to show considerably increased accuracy of dimensions, since they were not subject to deformation by hardening. Moreover, nitrided dies not only showed longer service life but also eliminated the tendency of the metal (particularly of brass) to stick to the working surface of the die. This resulted in a considerable increase in the speed of operation and production.

The second report,[4] which deals with the nitriding of austenitic steels, may be said to constitute a continuation of the work done by Jones,[5] whose findings concerning the disintegration of the austenitic surface into solid solution and nitride under the influence of the nitriding process are discussed. The report also records the fact that a series of investigations by magnetic methods made by a Russian metallurgist[6] fully confirmed the results arrived at by Jones. In this case steels of the following compositions were investigated :

(1) 18% Cr, 8% Ni. (2) 18% Cr, 8% Ni, 0·6% Ti.
(3) 18% Cr, 27% Ni, 3% Si. (4) 14% Cr, 16% Ni, 3% W.

According to the magnitude of formation these steels were classified as " energetic " (steel No. 2), " normal " (steels Nos. 1 and 4), and " weak " (steel No. 3). Reference is also made to prior work done by Norton[7] concerning nitriding at high temperature of alloys with high-aluminium percentage, and to the observations made by Ericson[8] concerning the X-ray examination of a Fe-Cr alloy.

The scope of the report reviewed here is defined as : (*a*) determination of the increase in hardness of austenitic steels by nitriding ; (*b*) clarification of the influence of the

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[2] P. E. Mochalkin, " Symposium of Stakhanovite Methods of Heat-treatment, 1938." (In Russian.)

[3] Tzerniak, *Metal Herald*, 1937, No. 16–17. (In Russian.)

[4] G. F. Kesolapov, " Nitriding of Austenitic Steels," *Metallurg*, No. 6, 1939, pp. 54–60. (In Russian.)

[5] G. Jones, *Metal Progress*, 1936, No. 2.

[6] A. A. Kuznetzov, *Journal of Technical Physics*, VII, 1937. (In Russian.)

[7] Norton, *Trans. Am. Inst. Min. Met. Eng.*, 1934.

[8] Erikson, *Strukturber*, III, 586.

TABLE III.

Nitriding Temperature, ° C.	Nitriding Time, Hours.	35XMYA.		3XB8.		4XBC.		X12M.		R.		I 172.	
		Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mn.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.
500	3	0·04	920	0·08	967	0·06	400	0·02	780	0·02	970	0·03	937
$500-\frac{570}{600}-500$	6	0·2	970	0·21	922	0·24	450	0·05	923	0·06	1,097	0·06	1,087
$500-\frac{570}{600}-500$	9	0·3	955	0·27	732	0·3	406	0·15	905	0·08	1,064	0·09	1,076
650	6	0·22	682	0·25	600	0·3	320	0·10	655	—	—	—	—

TABLE IV.

Steel No.	%.				Vickers Hardness.		Main Phase in Final Condition.	Depth of Case, Mm.	Structure after Nitriding.	
	Cr.	Ni.	Mn.	W.	Before Nitriding.	After Nitriding.			Of Surface.	In Case.
1	15	15	—	2·5	250	820	γ	0·15	$\gamma^1 + \eta$	$\gamma^1 + \eta$
2	15	—	15	2·5	320	850	γ	0·17	$\gamma^1 + \epsilon + \eta$	$a + \eta$
3	12	4	8	—	380	800	γ	0·17	$\gamma^1 + a$	$a + \eta$
4	15	—	15	—	280	900	γ	0·17	$\gamma^1 + \epsilon$	$a + \eta$
5	13	36	—	—	180	680	γ	0·16	$\gamma + \gamma^1 + \eta$	γ
6	—	36	—	—	160	185	γ	0·14	γ^1	γ
7	18	8	—	0·5	180	1,000	γ	0·14	$\gamma^1 + a$	$a + \eta$
8	—	—	16	—	270	700	γ	0·22	ϵ	$a + \epsilon$
9	13	—	—	—	220	900	a	0·32	$\gamma^1 + \eta$	$a + \eta$
10	13	—	—	3	340	920	a	0·26	$\epsilon + \gamma^1 + (\eta^2)$	$a + \eta$

nitriding temperature upon the magnitude and hardness of the case produced; and (*c*) study of the character of the structural changes obtaining in the case. The steels investigated are listed in Table IV. Hardness of the nickel steel No. 6 is seen to be hardly increased at all by nitriding; but the steels containing considerable percentages of chromium and manganese show greatly increased hardness after nitriding. This, it is stated, is in complete agreement with the findings of Jones.

In order to clarify the influence of the nitriding temperature upon the hardness of the case produced, a few steels were nitrided for periods of 24 hours at 500°, 580° and 650° C. The results of these test runs are listed in Table V.

TABLE V.

Steel No.	Nitriding Temperature ° C.					
	500.		580.		650.	
	Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.	Depth of Case, Mm.	Vickers Hardness.
1	0·02	450	0·08	860	0·12	800
2	0·02	320	0·08	950	—	300
3	0·02	450	0·12	800	0·16	840
4	0·02	300	0·09	930	—	300
7	0·02	330	0·11	1,200	0·14	850
9	0·12	1,050	0·26	890	0·38	600
10	0·06	1,000[*]	0·18	950	0·27	670

[*] 700 Vickers hardness with 10 kilogs. test load.

This table shows that the case of the non-austenitic steels Nos. 9 and 10 with *a* structure in the final analysis has considerably less hardness if produced at temperatures exceeding 500° C. As a matter of fact, at 650° C. the hardness of the case is almost reduced by one-half as compared to that obtained at 500° C. No such decrease in hardness occurs in the nitriding of austenitic steels at 580° C. In some of these steels no, or no substantial, decrease in hardness occurs even at 650° C. Excepting the two steels showing *a* in the final condition, all other steels show very little increase in hardness at 500° C. These readings are, however, quite misleading, as the low-hardness readings are due to penetration of the thin case under the test load of 10 kilogs. This is proven by the widely divergent hardness measurements obtained with steel No. 10. Here, hardness testing with 10 kilogs. load indicated a hardness of 700 Vickers, while repetition of the test with 5 kilogs. test load resulted in 1,000 Vickers.

The hardness of the austenitic steels Nos. 2 and 4, alloyed with manganese instead of with nickel, showed a pronounced decrease at 650° C. Examination of their microstructures showed a complete absence of any case. This result was somewhat unexpected, and five more runs at this temperature were made with steels Nos. 1, 2 and 4 without, however, producing any different result. A duplex cycle was also tried with steels Nos. 2 and 4. A hardness of 320 Vickers was measured after nitriding for 24 hours at 650° C. After the pieces had been once more nitrided for 24 hours at 580° C. a hardness of 850 Vickers was registered. It is difficult to explain why, unlike chrome-nickel steels, high manganese and chromium steels cannot be nitrided at 650° C. Nor can this phenomenon be explained by assuming the presence of an oxide surface film, as found by Jones when testing 26% Cr steel, since repetition of the nitriding process at 580° C. finally results in satisfactory diffusion of the nitrogen.

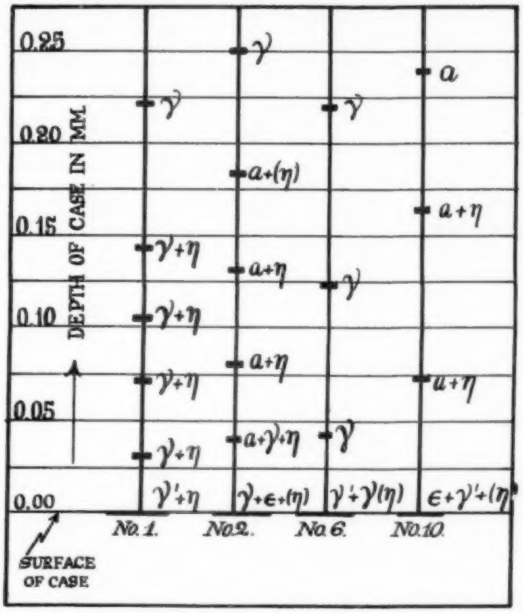


Fig. 3.—Phase distribution in surface and at various depths of case.

As Table V shows, with steels Nos. 9 and 10 having *a* iron in the final condition, a much thicker case was obtained than could be observed in the austenitic steels. The investigator claims that this delay in the diffusion of nitrogen with respect to austenitic steels must be due to the atomic crystalline structure rather than to the influence of the alloying elements. Nevertheless, it cannot be denied that the alloying elements can also influence the strength of diffusion.

A number of test-pieces, nitrided at 520° C. for 72 hours, were subjected to an X-ray analysis at various depths of the case. The results obtained with the steels Nos. 1, 2, 6, and 10 are given in Fig. 3. The surface condition of all steels is indicated in Table V.

The chief conclusions drawn by the investigator are that (1) the nitriding temperature required for obtaining highest case hardness of austenitic steels lies higher than that of steels originally having *a* iron; (2) in austenitic steels the diffusion proceeds much more slowly than in steels with *a* phase; and (3) with nitriding the γ phase in the case breaks down into *a* and nitride.

Institute of British Foundrymen

The gravity of the international situation has caused the cancellation of the Annual Conference which was to have been held at Cheltenham. Several informative papers were prepared for presentation at the technical sessions, and these are briefly summarised.

IN accordance with the normal rota, it had been arranged to hold the 1940 Annual Conference of the Institute of British Foundrymen at Middlesbrough. The outbreak of war necessitated that the matter be reconsidered, and it was decided to hold a Conference at an easily accessible centre. After careful consideration, Cheltenham was chosen and arrangements had proceeded successfully for holding the Conference on June 7–8; owing to the gravity of the international situation, however, and also because foundries are operating under high pressure, the Council decided to cancel the meeting. Even though the arrangements made had curtailed the time during which the Conference was to be held, and had been fixed for Friday and Saturday, when it was hoped to interfere with important work as little as possible, the demand for production in the industry has never been so acute as at present, and the Council were justified in cancelling the proceedings.

Several important papers were prepared for presentation at the technical sessions arranged in connection with this Conference, including an exchange paper from the American Foundrymen's Association, and as these are of a very informative character, it is proposed to give their salient features.

Chromium Heat-Resisting Cast Irons

THE present knowledge of heat-resisting cast irons is reviewed in a paper by R. C. Tucker, M.A., in which he deals more particularly with chromium cast irons, touching only lightly some of the special highly alloyed cast irons developed in recent years. Attention is directed to "hæmatite" as the simplest type of heat-resisting cast iron and reference is made to published reports of the Ingots Committee of the Iron and Steel Institute, which contain interesting information on the life of hæmatite cast iron ingot moulds. The conclusions inferred the use of 10% steel in the hæmatite charge, together with a phosphoric iron.

Mr. Tucker refers to the use of these in the manufacture of pig-casting machine moulds which were used in two new machines. In a few months, from one machine, came a serious complaint of major cracking, from the other a satisfactory report. Visits to the machines and careful investigation showed that the service conditions were widely different. The replace moulds for the cracked moulds were made in pure West Coast hæmatite, and the complaints ceased for a time. Later, however, several more orders were received, indicating a continuance of rapid failure and similar lack of satisfactory service from other suppliers!

A heavy mild-steel frame mounted on trunnions was made and a set of six moulds mounted on it:—

(*a*) Two in West Coast hæmatite of an approved analysis.

(*b*) Two of a 10% mild-steel mix with East Coast hæmatite and of almost identical chemical analysis.

(*c*) One mould of (*a*) plus 1% nickel.

(*d*) One mould of (*a*) plus 1% copper.

These were limed and repeatedly filled with molten foundry iron, and cooled with a hose as nearly as possible as in practice. They were rotated and tipped, "stickers" were removed with a crowbar and the underside was hosed for a similar period. They were then re-limed and refilled with molten metal as soon as possible. The two alloyed moulds showed early cracks at the lip, which gradually increased in size. The other moulds showed no sign of major cracking for 200 casts, except for some very small cracks on the lips, after 100 casts, which appeared unchanged after 200 tests.

The moulds were then placed in general use for casting spare metal in the foundry, and after several months without liming or quenching gradually failed by growth and the tearing out of lumps from the bottom by "stickers." This test produced as near as possible service conditions in a normal pig-casting machine, and agreed with the results obtained in the complaint-free machine. The other machine was operating in conditions which are comparatively new to the pig-iron industry, and these conditions led to rapid failure of almost any type of cast iron mould. The author is firmly convinced that the introduction of steel and phosphorus into an established good hæmatite mixture is a step in the wrong direction where heat shock is probable.

The high-duty cast irons, which have a rather more stable pearlite and finer graphite than ordinary foundry iron, are used for heat resistance, though usually for their mechanical properties. These two factors are claimed to result in superior growth resistance at 450° to 550° C., but at higher temperatures and for intermittent service the difference is very small. They generally are not resistant to scaling and heat shock, and on short-time tensile tests their strength is only maintained up to 500° C.

The next group consists of low-alloy cast irons designed for special purposes, in which the influence of special elements begin to be felt. These low-alloy irons are not resistant to heat shock and are only slightly more scale resistant than ordinary engineering cast irons. The properties which must be sought, therefore, are machinability, good foundry properties, growth resistance, toughness and strength at elevated temperatures. These low-alloy irons depend for their properties on very close control of the structure and analysis, and a combined carbon of 0·8 to 1·3% is aimed at in most cases. It is only possible to control the structure by the use of modern methods, as the old methods of chromium additions were uncertain.

The addition of chromium can be accomplished in various ways. Lump ferro-chromium in the cupola often spreads to other charges and is usually unsuitable except for melts of some tons collected in one ladle and well mixed. Ferro-chrome briquettes are much more satisfactory. Crushed 4 to 6% carbon ferro-chrome can be added to the cupola stream in amounts up to 0·6% chromium when treating small quantities of standard metal. If closer control of ladle additions is necessary, then powdered ferro-chrome is an unsatisfactory material (as is powdered ferro-silicon or ferro-molybdenum), because some of the powder is invariably blown away from the falling stream by air currents.

The most accurate and reproducible method of chromium addition is by the use of modern exothermic mixtures. Mention is made of a material of Canadian origin, marketed under the name of Chrom X, which is in the form of 10-lb. bricks, each containing 5 lb. of chromium and giving practically 100% recovery. It is easier to control chromium by this method than by any other simple and inexpensive method.

Various types of low-chromium cast iron used for heat-resisting purposes are given by the author from experience.

For low-temperature carbonisation retort castings operating at 700° C. the composition of the metal used is given as: T.C., 3·25; Si, 1·35; Mn, 0·6; S, 0·1; P, 0·3; and Cr, 0·6%. Another example concerns the manufacture of 9-ton chemical retorts (3 in. thick) for use at 850° C. In this case the composition was somewhat similar and comprised T.C., 3·25; Si, 1·2; Mn, 0·6; S, 0·1; P, 0·1; and Cr, 0·65%. Castings of this composition stood up well in service, and the temperature has been raised to 950° C. without decreasing the life. A more difficult problem is encountered in the manufacture of the Newton needle heat-exchange elements, because the thin sections and needles demand very fluid metal. It is necessary to determine the best composition and structure, not only to meet the service requirements, but to give little trouble in the foundry. Again, chromium cast irons have proved the most satisfactory, but over 1·0% of chromium is necessary with increased silicon to give the desired structure. The introduction of high-chrome to high-silicon iron gives less scaling and much less growth. The body of these castings may operate up to 650° C. and the needles in the gas stream up to 850° C. at their tips.

The author discusses, briefly, the testing procedure for scaling, growth and strength at high temperatures, and later gives some attention to the high-alloy cast irons which have been specially developed for heat-resisting applications.

Production of Pressure-Resisting and High-Duty Iron Castings.

MANY factors operate against the production of sound castings, even when conditions and circumstances under which they are made are normal. With the country at war, abnormal conditions prevail, making the usual difficulties greater and imposing others at a time when foundries are required to give a maximum output produced regularly to schedule. This is particularly true when the foundry is not laid out for the production of a large number of standard castings, but with a wide variety of castings both in regard to design and size, such as is characteristic of the jobbing foundry. It is in such a foundry that the production of pressure-resisting and high-duty iron castings is discussed in this paper by J. L. Francis, A.M.I.Mech.E.

The problem of providing correct metal for this type of work is not an easy one. The maximum adaptability arises, and the metal practice evolved by the author has to cater for castings of diverse weight, size and type, and simplicity of operation demands that grades of pig iron and scrap should be kept to a minimum and the number of different metal mixtures made as few as possible. The system developed embraces straight and alloyed grey iron castings, weighing from a few ounces to 2 tons. Metal sections range between $\frac{5}{16}$ in. and 1½ in. thick, hence the problem occasioned by excessive slow cooling of heavy sections yielding coarse-grained structures is not often encountered.

Pistons, cylinders, liners and valve covers form a class wherein resistance to pressure and wear is of paramount concern. Working pressures in some instances rise to as high as 1,500 lb. per sq. in. For these castings ease of machining is of secondary consideration. Intricate coring and wide sectional variations obtain to form water jackets and air spaces. Moreover, no leakage must take place between the water and air. Briefly, the castings are of just the kind most difficult to make sound and for which this property is of supreme moment.

The term "high-duty iron" used in this paper refers to material able to fulfil the requirements of British Standard Specification No. 786 (1938), which covers a tensile strength of from 15 to 22 tons per sq. in. obtained from the 0·875 in. diameter cast bar, machined to 0·564 sq. in. section.

To maintain systematic working and production of standard grades of iron, having constantly uniform chemical and physical properties, can only be attained by efficient chemical and metallurgical control. Pig irons and other components of the furnace charges must conform to specifications. Once standard analyses are established for given classes of work they should be maintained reasonably constant. Distinct grades of cast iron possessing known and reliable physical data facilitates calculations involved in design.

All the iron is melted in cupolas fitted with receivers, and the melting practice and the selection of charge components are based on this method of production.

Standard grades and mixings of iron suitable for special classes of castings are of little use unless the mixture charged, as distinct units, can be drawn off at the tap hole with their individuality maintained. Where circumstances permit the running of a cast with one grade of metal only, the problem is simple of solution. When the moulds to be cast for one day's work need different qualities of iron, charging and melting operations must follow a planned programme under close supervision. A system of melting is described which gives good results in practice. Tables are given of the raw materials used, the charges, the compositions of the resultant cast irons, their physical properties, and the names of castings for which particular grades are suitable.

High quality irons exhibit a greater tendency towards shrinkage during solidification, because the expansion due to graphitisation is not so great as in high-carbon grey irons, and the liquid contraction is not counteracted to so great a degree. Substantial percentages of phosphorus increase the range over which solidification takes place. For pressure-resisting castings of complicated design with ribs, bosses and abrupt changes of section, it is better to restrict this element to around 0·3%. Such castings have many places where feeding is impossible to apply. Thick sections naturally cool slowly with predisposition to formation of coarse grain and porosity. Therefore it is logical to avoid a composition which will allow these places to contain liquid metal longer than is necessary. It is noteworthy that the author favours a manganese content higher than the average. For all castings of the high-duty type the manganese content is from 0·75 to 1·0%.

Additions to cast iron of elements such as copper, nickel, chromium and molybdenum have done much to widen its field of usefulness by imparting new properties. For most applications, ruling out the highly alloyed special cast irons, the combined or total alloy additions are not required in excess of 2 or 3%, quantities which allow of introduction directly to the molten iron in the ladle. Special combinations of the alloy metals are available, so arranged that an exothermic reaction results and no temperature drop is caused. Ladle additions are more precise, suffer the minimum wastage of alloying elements, ensure that the alloys are just where required, and, providing proper precautions are taken in making the additions, no troubles from lack of solubility or homogeneous mixing arise.

Practical aspects in the production of several types of castings are discussed, and later paragraphs contain some principles of founding which have general application.

Development of Some Gating and Feeding Methods for High-Duty Alloys.

THE development of high-duty alloys during recent years, while being a tribute to the enterprise and ingenuity of the metallurgist, has taxed the resources of the foundryman in producing castings embodying the enhanced qualities implied by the results of metallurgical research. The foundry and metallurgical technique requisite for the production of sound, dense castings in the modern high-duty and alloyed irons, for example, is much more exacting than that which was required in other days for the cast irons of the period. Higher pouring temperatures are the general order, and dictate the use of more refractory moulding sands. High liquid shrinkage and short freezing range of the low-carbon high-strength grey irons, "Ni-Resist," "Ni-Hard," and similar alloys, demand more generous feeding measures than the grey-iron foundryman was previously accustomed to provide.

A steadily increasing demand for castings of these types of alloys indicates that they are performing satisfactory service. Whether methods of producing them are universally such as to utilise to the fullest extent the metallurgical improvements that have been demonstrated, is probably debatable, and a subject worthy of consideration by those interested in their promotion. It is not sufficient that these modern alloys should furnish some additional service value over that of material previously used; for true progress one must aim for the ultimate properties possible of attainment from alloys concerned. That this attitude has been taken by many pioneering producers of these alloys is certain; otherwise, regardless of the improved metallurgical qualities and higher properties obtainable in testing bars, such marked success, in competition with other metals and methods of fabrication, could not so far be attained or maintained.

It is recognised that discrepancy unavoidably exists between the metallurgical properties of sections of a casting and those obtained from a standard form of test-bar, owing to the diverse structural characteristics, produced by differences in cooling rates, occurring in the varying designs of castings. It is essential, however, that the foundryman should take all precautions against this discrepancy being widened by porous discontinuities produced by inadequate feeding. Gating and feeding proportions may be such as to provide a minimum or maximum density in a casting, above the range where rejection, due to visible defects, occurs. Minute porosities resulting from minimum feeding provision will usually be reflected in lowered strength and lessened resistance to wear, abrasion, cavitation and corrosion.

A number of variables are present when planning the proportions and location of gates and feeding heads for an unfamiliar design of casting. In foundries engaged in quantity repetition work, it is feasible to determine, on a trial basis, the most effective and economical moulding technique for a particular design, before going ahead with production. This process is not, of course, practical where the miscellaneous jobbing foundry is concerned, except in minority instances, where a large number of castings from one pattern design are required.

The methods described in this exchange paper of the American Foundrymen's Association, by A. E. Cartwright and C. C. Brisbois, were evolved to meet the requirements of the extremely miscellaneous jobbing foundry with which the authors are concerned. Experiments were initiated about four years ago with the object of reducing the sensitivity to the variables prevalent in ordinary methods of gating castings weighing from a few ounces to 2 tons, made in both ferrous and non-ferrous alloys, including various tin bronzes, brasses, manganese and aluminium bronzes, silicon bronze, nickel silvers, Monel, and commercially pure nickel, as well as the alloyed irons mentioned above.

The main feature discussed in this paper is that of dispensing with the separate introductory gate and pouring directly and entirely through the feeding head. This principle of direct riser pouring provides the following advantages:—

(1) Much enhanced effectiveness of feeding by having the feeding head filled last with hottest metal, and maintenance of feeding head temperature by virtue of the head being covered with a heated strainer core.

(2) A moderate economy in feeding metal and gates, together with a large economy brought about by reduction in the number of defective castings.

(3) Much lessened sensitivity to feeding head proportions for different casting designs and alloys of different shrinkage characteristics—that is, the feeding head is generally of a size to compensate for a range of shrinkage wider than that provided for by the more usual methods.

(4) Generally lower requisite pouring temperatures for all alloys, with corresponding less necessity for excessive superheating of the molten alloy. The last is an especially attractive feature from the metallurgical standpoint where those alloys most susceptible to oxidation or gas absorption, beyond their melting point, are concerned.

Some readers will be rather sceptical of this method, but the authors do not desire to imply that direct feeding head pouring is uniformly applicable to all designs other than the exceptions discussed; for many castings, particularly those having no complications in sectional design, it is freely admitted, and indeed emphasised, that the more ordinary gating methods are adequate and more economical. Nevertheless, they assert that a large proportion of the varied designs passing through the foundry have most profitably been adapted to this method of production, and the resultant castings have, in many instances, shattered standing records of service life.

Design of Test-Pieces for Carbon Steel Castings

THE design of test-pieces which are truly representative of the metal employed in the manufacture of carbon steel castings has not received the attention merited by its importance to the steel castings industry. For many years a block or coupon of the rectangular tongued type from which two test-pieces could be cut in a plane parallel to the axis was generally employed. This design is open to the serious technical objections involved in a square section prone to the formation of cleavage planes from the corners at 45° to the faces. In spite of this objection, this method usually produced two test-pieces of reasonably uniform properties.

When, however, the tongue of the block was extended to provide a third bar (either as a spare or for a third test), it was found that the three bars did not possess uniform properties. It has been shown that the bottom bar had the best properties, the bar immediately under the head the next best, whilst the centre bar was slightly inferior. These results are independent of the position of the gate, similar results being obtained whether the gate is in the base or the head.

An explanation was offered that the bottom bar consisted entirely of primary crystals, whilst the two above it had centres of secondary crystals, the formation of which in the narrow space between the primary crystals prevented the effective gravitational feeding of the middle bar.

The growing tendency of inspecting authorities to demand three tests (usually tensile, bend and impact) has made imperative the use of a block which will yield three test-pieces of exactly uniform properties. This paper, by C. H. Kain and E. W. Dowson, describes the steps taken in the foundry with which the authors are connected to evolve such a test-block.

A block was designed to employ the principle of directional solidification by making the casting taper from the base to the feed head. After various tests modifications were made and a final design was then adopted having a section resembling a clover-leaf. The authors recommend this test-block and give rules governing its design, together with data in support of their recommendation.

Gas in Liquid Cast Iron

THE subject of this paper, by W. Y. Buchanan, is rather difficult to approach owing to the many experimental difficulties, and the procedure adopted should receive due consideration initially. The many variables entering into ordinary cupola melting make the direct application of this research to the cupola in everyday practice lengthy and sometimes confusing. However, the paper is intended mainly to promote discussion.

In order to improve the conditions of the tests a new ladle was made and drilled all over the sides and bottom, with ¼ in. diameter holes to facilitate the escape of steam during the drying of the lining. A block pattern was made to form the lining 1 in. thick all over the bottom and sides, and used for ramming up. Prior to this, there was a tendency to make the bottom of the old ladle too thick and the sides too thin, and any variation in thickness of the refractory altered the cooling rate of the metal. This cooling rate was always checked by plotting a time-temperature graph for each test. With the new system a very smooth, even lining was obtained and this was dried very thoroughly with the "Aurora" burner used for lighting the cupola, by applying the heat to the outside as well as the inside of the ladle. The ladle was knocked out after each day's tests and made up afresh before the next in order to ensure reasonably identical conditions; no black-wash was used on the surface of the lining.

It is interesting to note that the introduction of cold material appears to liberate large quantities of gas from liquid cast iron. This is shown in the case of steel additions referred to in the paper. The use of the bell which constitutes a cold addition may have the same effect. This would explain why the large evolution takes place immediately on placing the bell in position in the surface of the metal, irrespective, within limits, of the initial temperature.

The author discusses the measurement of temperature of the molten iron and the type of apparatus required for the analysis of small volumes of gas collected from liquid cast iron. Moisture has been shown to be a serious source of gas in molten metal, and the author discusses measurement of the moisture content of the atmosphere and considers the idea of drying the blast. Particular reference is made to the results of direct practical trials of the application of dried blast by E. H. Lewis, but the conclusion arrived at is that normal variations of furnace condition throughout the blow have more influence on the gas composition than the moisture content of the blast itself.

In spite of the conclusions drawn from the latter work done on the possible relation between gas content and atmospheric moisture it was thought that the presence of water in the blast must have an important effect on the nature and quantity of dissolved gases, and it was decided to introduce water into the blast and observe the effect. It was deemed unwise to apply this to a cupola on normal production owing to the risk of producing defective castings, so the trial was made on a 32 in. cupola melting metal for pigging only.

This experiment showed that the presence of water in the blast had a pronounced effect on the quantity and composition of the dissolved gases. It is also possible that other types of cupolas—e.g., the single-row Rapid type—will react differently from the experiment recorded, and that charges containing large percentages of scrap in a Rapid type of cupola may be more adversely affected by high moisture conditions owing to the high concentration of the blast in certain parts of the cupola.

Experiments with steel additions to the ladle were undertaken to find what effect, if any, this had on the volume and analysis of the dissolved gases. It is shown that the effect of steel additions is to reduce the gas content, in the case of low initial content by about 30%, and in the case of high initial gas content by 54%. It was intended to test the effect of various alloy additions on the gas content of the metal in the ladle, but this field was not covered.

Some Observations on Contraction in Grey Cast Iron

THE amount of contraction and degree of distortion in a casting will have relationship to the chemical and physical properties of the metal, design and method of manufacture. Factors influencing contraction include —

1. Chemical composition of the alloy.
2. Melting conditions, pouring temperatures, and superheat of the metal.
3. Design, section and volume related to section.
4. Size, shape, location and distribution of runner and riser gates.
5. Character of the mould and core materials and their condition when the metal is poured into the mould.
6. Method of moulding and core-making.

In this paper, by E. Longden, A.M.I.Mech.E., the influences stated above are not detailed, but the author gives further information about the behaviour of castings during cooling, a subject to which he has devoted much study. In the past, standard allowance has been laid down for cast iron, irrespective of its very varied constitution, or size and design of the casting. This does not mean that standard allowances for contraction have been adhered to; they have not. Actually, the allowances made vary considerably in different shops and in the same shops on different classes of work. The observations which the author makes, therefore, are as important to the pattern-maker as to the foundryman, because this subject is one which makes foundry experience essential to the pattern-maker.

It is known that arrests in the rate of contraction are quite pronounced in the general run of cast irons. Such volume changes would be largely due to the liberal amount of carbon present in cast iron, and its condition. The precipitation of primary graphite on solidification, and secondary graphite at lower critical temperatures, will account for expansions. Generally, it has been considered that there are two distinct arrests in low-phosphorus irons, and, in alloys with appreciable phosphorus content, three arrests.

The final amount of contraction will be influenced by the ratio of free carbon to combined carbon in the completely cooled casting, but the data presented by the author indicates that final contraction and the absence or presence of stresses in many classes of castings are also due to the conflicting expansion and contraction influences operating together in the same casting. In lengthy castings, mould and core resistance will tend to reduce contraction and create stressed material.

A method devised by the author for ascertaining the behaviour of large castings during cooling, from the point of solidification to atmospheric temperature, is described in the paper. The movement of the casting is followed by frequent measurements between fixed points outside the mould and rods held by the metal of the casting. Whenever practicable, temperature readings are associated with the volume changes. The example chosen to describe the procedure is that of a lathe bed.

Several other tests on large castings are described, all of which offer substantial support to the previous experiments carried out by the author and presented to the Institute over a number of years.

They enable the author to conclude that, on the classes of iron castings surveyed, thick bars, or sections, contract more than thinner bars, or sections, where such varied sectioned members are linked together, as a single-piece casting, in a proximity to be affected by mutual influences. If, however, the same contrasting sections are cast as simple uniform and separate items, contraction is in line with standard allowance and knowledge—that a thin section of grey iron contracts more than a thicker section for the same analysis, because of the more rapid freezing of the lighter section and the effect of this more rapid cooling on the grain size and graphite formation.

A probable explanation of the two contrary degrees of contraction referred to is that, in the case of a one-piece casting, the thin or comparatively light sections are subjected to an extensional stress, during freezing and cooling of the metal, created by the resistance of the thicker sections which are not ready to contract. The frictional resistance of the mould and cores, and the expansion of cores on being cast, may be undergoing an expansion at a time when a thinner section has passed its expansion phase and is in a state of contracting. Under these conditions, the thin sections will suffer extensional stress.

Conversely, the thicker sections will be subjected to a compressional stress by the effort of the earlier cooled members to contract. Finally, the heavy sections, on cooling, must take up a shorter length by bending certain sections of the casting, or by fracture in the weakened or most highly stressed sections.

Recent Developments in Materials, Tools and Equipment

Gas Conditioning Units Applied to Paint and Varnish Manufacture

THE introduction of protective atmospheres into the heating and cooling chambers of heat-treatment furnaces, which are provided with special sealing devices preventing both the escape of the gas and the inward seepage of the atmospheric oxygen, has greatly increased the refinements possible in heat-treatment operations. The use of suitable atmospheres for the bright annealing of ferrous and non-ferrous materials, for instance, not only effects a great improvement in the surface finish, without any detriment to the properties obtained by the treatment, but entirely eliminates the high cost of secondary cleaning operations. The application of this process has become essential in those industries which are concerned with high-quality products because of consequent economies that can be effected in production costs.

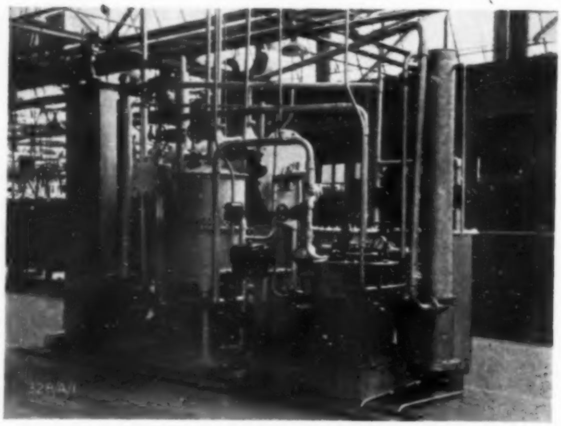
For many years the Incandescent Heat Company Ltd. have specialised on the production of gas-conditioning plants for this purpose. These units, which are manufactured with capacities ranging from 500 to 10,000 cu. ft. of conditioned gas per hour, usually employ standard town's gas as a base, the volume of conditioned gas produced being three to four times that of the base gas used.

The use of chemical atmospheres of known and controllable composition, however, is not confined to the heat-treatment of metals; it is applicable to many other branches of industry and has been successfuly applied to paint and varnish manufacture. Its introduction to this country, after being adopted for this purpose in the United States, has evoked considerable interest, and, for this reason, its advantages and principal operation can profitably be summarised here.

1. The inert gas produced by the apparatus is a complete substitute for CO_2 at a very small fraction of its cost.
2. The mixing and agitation of synthetic varnishes are accomplished with increased efficiency and superior colour control.
3. The gas applied to varnish kettles is inert.
4. The gas may be applied to storage tanks with complete prevention of oxidation and skinning.
5. The inert gas is a reliable means of protection against the outbreak of fire.
6. Pipe-lines are blown out and kept clean.
7. Operating costs including maintenance, depreciation, and all other items, are extremely low, as compared with savings effected, for instance, the cost of liquid or frozen CO_2 varies between 20s. and 25s. per 1,000 cu. ft., compared with approximately 6d. per 1,000 cu. ft. for the new gas manufactured from standard town's gas.

Description of Plant

The base gas is fed into the system and controlled by a Selas electrically-driven quality governing mixer, which maintains, with precision, correct air-gas ratio proportioning. The gas is then burned in a refractory-lined combustion chamber, and passes from this chamber for primary and secondary dehydration. Primary dehydration is of the ordinary surface condenser type, and the secondary and final dehydration is by means of the regenerative silica gel system. Finally, any remaining traces of sulphur are removed by the desulphurising unit, from which the gas passes into a compressor, and is ready for delivery to the storage tanks, resin kettles or for other operations about the plant.



Conditioning unit for producing 1250 cu. ft. per hour of inert gas.

The silica gel unit consists of two absorbers containing the necessary charge of silica gel complete with activation fan, and also, necessary connecting pipework and valves. This unit works on the principle of one adsorber drying whilst the other adsorber is being re-activated by the passing of hot air through the silica gel; and the heat of combustion is utilised to the best advantage and efficiency of the plant.

The equipment is completely automatic. The amount of gas is co-ordinated with the demand for inert gas at the point that is drawn from the line. The high-pressure compressor, which delivers the gas as required, is provided with automatic equipment, to idle when the demand is cut off, and to open when the demand arises. Governors are provided to maintain pressure in the storage tank at a constant value, and to operate the compressor so as to obtain this result. One important feature is the Analygraph, which is arranged to take a continuous sample of gas as manufactured, and record on a chart any variations in the gas compositions.

Typical Gas Composition

The gas produced by the generating unit may be adjusted to have a wide range of different compositions. In the paint and varnish fields, its widest application is to supply a strictly neutral inert atmosphere, which will not support combustion and which has no appreciable fuel value, so that it cannot be burned. A typical analysis of this gas is given below:

Carbon dioxide	10%
Carbon monoxide	1·9%
Oxygen	0%
Sulphur	0%
Oxides of Nitrogen (traces)	0%
Water vapour	0·1%
Nitrogen	88%

It will be noted that the gas is substantially carbon dioxide and nitrogen. The water vapour content can be kept down as low as 0·1% by the use of the silica gel plant, and the temperature of cooling water on primary condensers, which varies considerably during summer and winter, has no appreciable effect.

A plant of this kind to supply approximately 1,250 cu. ft. of conditioned gas per hour at 35 lb. pressure is shown in the accompanying illustration. The running costs for such a unit will vary somewhat according to local charges for electric power, water, and town's gas, but the costs are low and cover the power required for the 1½-h.p. Selas gas and air mixer motor, the ¾-h.p. fan motor, and the 4-h.p. compressor motor; 300-400 galls. of cooling water per hour for the condensers; and approximately 250 cu. ft. of town's gas per hour.

Precision Instruments for Testing Metals

AT the present time, when speed and accuracy in testing materials play such an essential part in the manufacture of precision equipment, testing instruments of the most exact and reliable type are a vital necessity. Within the last year or two a number of ingenious instruments have been designed for such purposes at the Salford works of The General Electric Company Ltd., and details of several may be of interest to readers.

One measuring instrument which has been found to be of exceptional value in metallurgical circles is a fatigue tester. It provides a rapid method for testing the quality of steel bars and non-magnetic metals. The principle upon which the instrument operates is comparatively simple. Actually, the instrument is in two parts, one a vibrator unit, and the other a power supply unit, while a recorder can be attached for indicating purposes. To test a steel bar or rod the metal is placed on the vibrator unit, supported at its two nodes. It is vibrated electro-magnetically, so that it resonates, a method that allows a very great number of cycles of stress to be applied to the bar in a relatively short time. By measuring the deflection of the bar at an antinode, the actual stress applied can be calculated using the modulus of elasticity E, which can be determined from the frequency of the vibrating bar ; the number of cycles applied to the test-bar before failure is indicated by a recorder.

Another recently-introduced measuring instrument is designed for testing the hardness of thin metals. Hardness testing instruments usually work on the well-known principle that a steel ball of certain dimensions makes, under a certain load, an impression giving the number corresponding to the particular hardness. The usual type of instrument working on this principle is suitable only for sheet metals which are thicker than 0·5 mm. The G.E.C. instrument has been designed to measure very thin metal sheets or foils, and makes an impression of only two or three thousandths of a millimetre, and it is therefore suitable for hardness measurements on thin sheets and foils of the order of two or three hundredths of a millimetre in thickness. Such a slight impression in the case of a Rockwell Tester would give a deflection of only two or three degrees, so that it would not be possible to ensure accurate measurement.

An electric micrometer has also been designed to indicate the thickness of any foil and sheet metal. Two types of the instrument are made, both embodying the same principle. One is for use with rolling-mills where the measurement is made whilst the foil is being rolled, and any departure from the required thickness is shown continuously. The second type is for the measurement of pieces of foil after manufacture and the actual thickness is indicated directly on the scale of a galvanometer.

Still one more instrument has been made available to the metal industry. This instrument is intended for measuring the thickness of any non-magnetic coating on a magnetic base, but is not designed so that it can be used for magnetic coats or for non-magnetic coats on non-magnetic base. The instrument is in portable form, with an exploring head connected to the instrument by means of a flexible lead. The instrument can be supplied to measure layer thicknesses within the following limits : from less than 0·001 in. to 0·022 in., and from less than 0·005 in. to 0·030 in.

By designing and marketing such instruments, the G.E.C. is assisting very materially to promote higher standards in quality and accuracy in the products of the metal industry. Detailed particulars of each of the instruments referred to can be obtained on application to the company.

The Carborundum Company Ltd., Trafford Park, Manchester, manufacturers of abrasive and refractory products, have appointed Mr. R. Douglas Robin as their representative in the Glasgow and South West Scotland area, in succession to the late Mr. Gordon D. Hardie. Mr. Robin resides at 17, Broom Road, Newlands, Glasgow, S.3.

Fittings for Night Works' Illumination

THE General Electric Co., Ltd., has just introduced a range of A.R.P. angle fittings for the illumination of essential night work on building construction, docks, shipyards, railways and in similar situations. The work carried out in such situations frequently calls for good illumination on vertical surfaces, or for illumination from the side of relatively large horizontal areas in which the placing of poles for normal overhead lighting would cause obstruction. Special fittings are necessary in each circumstance since peace-time fittings normally utilised for such situations involve emission of light direct from the reflector above the horizontal, thus contravening blackout regulations.

The range comprises a series of angle lighting reflectors and cowl fittings, both types being designed to direct the main beam of light forward without permitting any direct light above the horizontal. It has also been found under test that the use of these fittings increases both output and quality of work.

The angle-lighting reflectors are constructed in lead-coated mild steel, painted black outside and partially white inside. They are suitable for use with general service lamps of 40–200 watts, and are supplied complete with lampholder. An adjustable pole clamp is fitted to accommodate poles from 3 in. to 5 in. in diameter.

The cowl fittings which enable existing 12 in. or 14 in. reflectors of the standard dispersive, angle, or concentrating types to be adapted for use in the blackout are made of lead-coated sheet steel. They are painted black inside and out and have visor bands for attachment to the reflector. Adjustable pole clamp bracket mountings suitable for poles from 2 in. to 5 in. diameter are included.

A feature of the cowls is that the mounting bracket is so designed as to prevent the fitting being tilted either sideways or at too high an angle forward. This makes certain that no light can be emitted above the horizontal and the light distribution is substantially the same as that obtained from a self-contained fitting.

With the use of either of these fittings, it is possible to direct far more light on to the points where it is required without running the risk of excessive illumination intensities immediately below the fitting. When they are about to be installed it must be remembered, however, that exemption from the lighting order will have formally to be obtained from the Police, who may require to be satisfied that regulations are not contravened. We understand, incidentally, that these G.E.C. fittings have been demonstrated to the satisfaction of the Ministry of Home Security and the Home Office (Factory Inspector's Dept.).

Full details of the fittings, with particulars of mounting heights, suitable power lamps, etc., are obtainable on application to the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C. 2.

Catalogues and Other Publications

"Wild-Barfield works and Laboratory Furnaces."—A revised edition, containing numerous improvements and including the several new types of furnaces that have been introduced since the last edition of this catalogue appeared in 1935. The main sections of this catalogue are also issued as individual leaflets, so that any who are interested in only one type of furnace, out of the many types available, can receive one or more leaflets instead of a more bulky catalogue. The catalogue is priced throughout, well illustrated, and contains ample data. Hand and automatic temperature controllers, and pyrometers are also included.

"A complete Service in Industrial Heat Engineering."—A two-colour brochure which describes the industrial furnaces and equipment of the Incandescent Heat Co., Ltd. ; the industrial heating plant and combustion equipment of the Selas company ; the industrial ovens and air conditioning plant of Controlled Heat & Air Ltd. ; and the industrial electric furnaces of Metalectric Furnaces Ltd. The main offices of the Incandescent group are in London, Birmingham and Manchester, and the last page of this booklet gives a list of the countries in which the Group has sales representatives.

Business Notes and News

Control of Light Alloys

The Minister of Aircraft Production, Lord Beaverbrook, announces that Mr. F. S. Spriggs has been appointed chairman of the Light Alloy Committee, and the members are Mr. W. C. Devereux, Mr. F. S. Mitman, Mr. H. W. Clarke, and Mr. P. Pritchard. This committee will expedite the control and supply of light alloys throughout the country. They have complete authority.

Import Licensing of Non-Ferrous Metals

With reference to Notice to Importers No. 57, relating to import licences for certain non-ferrous metals and alloys (excluding aluminium), importers are advised to observe the following instructions in completing application forms in order to avoid delay in the issue of licences :—

(1) In space 13 state the description of the goods for the manufacture of which the metal is required.

(2) In space 14 state—

  (*a*) the contract numbers when the goods are required for Service orders,

  (*b*) the country of destination in the case of goods intended for export.

(3) A separate statement should accompany the application form stating—

  (*a*) the steps which have been taken to obtain supplies of the metal in this country and with what result,

  (*b*) in cases where the metals are required for Service orders, whether similar material is being used for implementing orders other than Service orders.

Importers are reminded that applications for import licences should be submitted in duplicate direct to the Non-Ferrous Metals Controller, Ministry of Supply, Grand Hotel, Rugby.

Airframes and Alloy Steels

The Ministry of Aircraft Production has announced the appointment of an emergency committee to deal with airframe production. The chairman is Mr. F. S. Spriggs, of Hawker-Siddeley, and members include Mr. C. R. Fairey, of Fairey Aviation, and Mr. A. Dunbar, of Vickers-Armstrong. The committee has been given full authority with the object of speeding up production.

A further emergency committee has been appointed to deal with the immediate position of alloy steels required for the aircraft and aero-engine industries. It will have full authority to deal with all questions relating to the supply and disposition of these steels. The committee includes Mr. Arthur Matthews, chairman, Mr. A. B. Winder, Mr. G. Steel, Mr. L. Chapman, Mr. S. G. Newton, Mr. F. C. Harrison, Mr. H. Williams, and Major E. W. Senior.

Fischer Bearings Controlled by British Timken

British Timken, Ltd., have acquired the controlling interest in Fischer Bearings Co., Ltd. This step will affect production of key components for aircraft, car, railway rolling stock and machine tool construction, and, indeed, for almost any rotating plant and equipment.

Fischer Bearings was founded by the German concern Kugelfischer A.-G., and began production in Britain in 1936. The company occupies a substantial portion of the old Sunbeam car works and employs a large number of workers in the production of all sizes of ball bearings. British Timken, with extensive works in Birmingham, are claimed to be the largest tapered roller bearing makers in the Empire, and are also large manufacturers of parallel roller and ball bearings. They began ball-bearing manufacture six years ago, and the new development will greatly strengthen their manufacturing and technical resources in this field. It is understood that the Directors intend to concentrate on the manufacture of ball bearings at Wolverhampton. This will give much needed room in the Timken works at Birmingham for the expansion of tapered roller-bearing production.

Mr. Michael Dewar, Chairman of British Timken, Ltd., has assumed the chairmanship of Fischer Bearings Co., Ltd. The election of Mr. Dewar and Mr. F. J. Pascoe, Financial Director of British Timken, Ltd., to the Fischer board was announced recently.

Bairds and Scottish Steel Limited

The £300,000 extension scheme of the Gartsherrie works of Baird and Scottish Steel, Ltd., has been started and expected to be completed next year. The scheme includes the erection of a battery of 35 coke-ovens and auxiliary by-product plant, etc.

Stainless Steel Export Group

An export group has been formed under the name " Stainless Steel Manufacturers Export Group," in accordance with recommendations made by the Board of Trade. The chairman is Mr. C. E. Holmstrom, director of Firth-Vickers Stainless Steels, Ltd., and the secretary, Mr. Edward J. Gadsby (who is also the secretary of the Sheffield Stainless Steel Manufacturers' Association, 44, Bank Street, Sheffield, 1.

The group which is now formed will welcome the co-operation of all firms who are interested in the exportation of stainless steel, and it would appear desirable for such firms to communicate with the secretary at the address indicated above.

Iron and Steel Control

The Minister of Supply has issued Direction No. 2 dated May 25, 1940, under the Control of Iron and Steel (No. 8) Order, 1940. The Direction substitutes new schedules of sheet prices for those hitherto ruling, the effect of which is to provide a special price for thick sheets or light plates 3 mm. thick and over when these are rolled on a sheet mill. The demand for this class of material is such that it is necessary to secure production in sheet mills which do not normally roll these thicknesses.

In future, the maximum price and extras for sheets or plates 3 mm. thick and over when wholly rolled down in a sheet mill will be the same as for sheets immediately below 3 mm. Other prices, including the price of light plates made on plate mills and prices from merchants' stocks for plates and sheets however made, are unaltered.

New Experimental Station of Bureau of Mines at Salt Lake City

A new Intermountain Experiment Station of the U.S. Bureau of Mines was recently officially opened in Salt Lake City, Utah. The building is situated on a 4-acre site deeded to the United States Government by the University of Utah. Small laboratories are provided for chemical, physical, and microscopic experiments ; and large laboratories for metallurgical and ore-dressing experiments. Particular attention has been given by the Bureau of Mines to the application of modern physics to the solution of metallurgical problems ; and the physical laboratories reflect this emphasis in their unusual and highly specialised equipment, much of which has been designed by the Bureau's own experts. The new building, with its modern equipment, will facilitate the conduct of the long-standing co-operative programme of research conducted by the Bureau of Mines with the University of Utah.

The completion of the new building marks the fulfillment of a long-cherished plan for a large experiment station in the Intermountain area, and the Bureau of Mines has now moved the headquarters of its Metallurgical Division from Washington, D.C., to Salt Lake City, where they are near the metallurgical research of the Bureau being conducted at stations west of the Mississippi.

Electric Integrator

A young Soviet scientist, L. I. Gutenmacher, employed at the Power Institute of the Academy of Sciences of the U.S.S.R., has developed a new theory of solving problems in mathematical physics. On the basis of this theory, he has constructed an electric integrator by which it is possible to solve complex differential equations. Because of its simplicity, universality, and low cost, the electric integrator can be widely applied to the solution of complex problems in electrotechnics, thermotechnics, building mechanics, hydro-mechanics, aeromechanics, metallurgy, and other branches of science and industry.

Mr. Gutenmacher read a paper on his discovery, and demonstrated the integrator at a recent session of the Presidium of the Academy. Academicians N. M. Krylov, P. L. Kapitsa, S. L. Sobolev, and other eminent scientists are of the opinion that this discovery provides a powerful instrument for scientific research and the solution of practical problems. The Presidium of the Academy of Sciences of the U.S.S.R. has decided to introduce Mr. Gutenmacher's new method in research institutes, technical schools, and factory laboratories.

Reviews of Current Literature

Non-Ferrous Foundry Practice

For some reason, which is not very obvious, the number of books which deal with non-ferrous foundry technique is relatively small, yet it is the oldest section of foundry practice and that upon which the production of castings in ferrous metals was originally based. That the subject offers considerable scope for a useful book is evident on reading the combined work of the authors in this book. It embraces the technical developments of recent years and combines metallurgical as well as foundry practice. Modern foundry depends to a considerable extent on metallurgical technique and, in combination with foundry practice, a careful study of the subject as presented will facilitate the work of the founder.

The subject matter is very comprehensive and embraces the production of castings in the chief non-ferrous alloys, comprising tin bronzes, including lead and phosphor bronzes; aluminium bronzes; silicon bronzes; silver brasses; nickel silvers; copper nickel alloys—particularly Monel metal and its varieties; and aluminium and magnesium alloys. Considerable attention is given to sands, alloying and melting the metals, and the gating and running of castings. Information on moulding practice for each group of alloys is preceded by a consideration of the constitution and properties of the whole range of alloys in the group, which includes constitutional diagrams, microstructures, mechanical properties and uses. Useful information is given regarding compositions and test figures required by many recognised specifications for various alloys. Many important proprietary alloys are also included.

Although admirably suited to the needs of the non-ferrous foundrymen, especially those who have already given some attention to metallurgy, this book will be found as useful to metallurgists, particularly those specialising in this branch of casting production. In addition, however, the comparative advantages of alternative materials available, together with the sound information on foundry practice, is of considerable value to the designer. It is important to emphasise the latter aspect because, unfortunately, foundry practice does not receive the attention of designers that it should have. Collaboration between the designer and foundryman is increasing, but it is greatly facilitated when the designer is familiar with the fundamentals of foundry practice; difficulties are then more readily understood and solved. This additional knowledge not only assists in the successful production of castings, but in producing them more economically, and a study of this book would help the designer to a better understanding of the technique involved.

The authors have presented the subject matter in a very useful form, and the book is well illustrated and admirably produced; it is strongly recommended as an addition to the foundry literature for foundrymen and to metallurgists and designers directly associated with the production or use of non-ferrous castings.

By J. Laing, A.M.I.Brit.F., and R. T. Rolfe, F.I.C., M.I.Met. Published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 21s. net.

The Corrosion of Iron and Steel

A General Account of the Work of the Corrosion Committee of the Iron and Steel Institute and the British Iron and Steel Federation.

The problems arising from the corrosion of iron and steel are very serious and of great economic importance. Although authorities differ in their estimates of the wastage of iron and steel from this cause, the amount is recognised to be very high. Corrosion causes a large tonnage of iron and steel to go out of use each year, and while much is recoverable as scrap, the effects of oxidation results in much of it being a complete loss; it is not surprising, therefore, that methods are continuously being studied with the object of reducing wastage from this cause.

It was with this object that the Iron and Steel Institute and the British Iron and Steel Federation set up a Corrosion Committee in 1928. In an effort to embrace the whole problem as it applies to iron and steel the Committee has conducted extensive experimental work and exposure tests, designed both to ascertain the facts concerning the corrosion of these materials and to determine the best preventive means. The results of this investigation have been published in a series of five Reports issued by the Iron and Steel Institute. These Reports contain full details of the work undertaken in the investigation which enables research workers throughout the world to assess the value of the results obtained. Published in this form, the Reports present difficulties to the practical man, particularly in selecting the essential data to enable him to make use of the results of the investigation, and it is the purpose of this book to present the results of the investigation in a more practical form, yet accurate in detail, in order to make the results of this important work more widely known.

The author, Dr. J. C. Hudson, is Official Investigator to the Committee, and the book has been prepared on the instruction of the Committee to publish a general survey of the results of its first ten years' work with emphasis on their practical implications. Important features presented and discussed in the book are the results of world-wide field-tests, conducted at 14 corrosion stations, seven of which are overseas, on the atmospheric corrosion of commercial irons and steels. Data are given for the comparative resistance to atmospheric corrosion of wrought irons, ingot iron and structural steels, and the effects of varying alloying elements, such as copper, on the resistance of low-alloy steels when exposed in the bare condition. In addition, detailed recommendations, based on the results of painted specimens, are made for protecting structural iron or steelwork by means of paint, which, if followed, will double or treble the life of the initial paint, as compared with ordinary procedure. The corrosion of iron and steel under marine conditions is discussed on the basis of direct experimental work, including service tests on steel shell plates built into actual ships, and of observations of cases of excessive corrosion of ships' hulls. The oxidation of iron and steel at elevated temperatures is also discussed, together with the effect of rolling scale on the rusting process. An account is also given of the activities of the Protective Coatings Sub-Committee, which is concerned with practical methods of protection for ferrous products. The book also includes descriptions of investigations of atmospheric corrosion of wires, and of the corrosion of steel sleepers; the present state of knowledge of soil corrosion is also surveyed.

It should be emphasised that this book is not a scientific treatise; it is essentially practical, and is based on those aspects of the subject which have been studied or discussed by the Corrosion Committee, thus the great majority of the statements made by the author are based on first-hand evidence.

The task of the author has not been without difficulties, but he has succeeded in presenting an authoritative work on corrosion, full of reliable information, and one which will be invaluable not only to the iron and steel trade and the associated industries, but to all concerned with the fabrication and sale of iron and steel products. It is not so much concerned with the record of work done on this subject as on the essential data which has resulted

By J. C. Hudson, D.Sc., D.I.C., A.R.C.S.; with an Introduction by Dr. W. H. Hatfield, F.R.S. and Dr. T. Swinden; published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2; price 18s. net.

The Anodic Oxidation of Aluminium and its Alloys

MANY methods which have been developed for the surface treatment of aluminium and its alloys are applied in practice. They cover a very wide range but may be divided broadly into two main categories, according to whether they depend ultimately on chemical or mechanical means. The former may be sub-divided into three groups embracing purely chemical methods, which include ornamental finishing and immersion processes; physico-chemical methods, covering diffusion processes, cementation, and oxidation by heating; and electro-chemical methods, which include anodic oxidation and electro deposition. The mechanical methods embrace pressure plating, polishing, spray coating, painting and various types of ornamental finishing. The whole subject of surface-treatment, therefore, embraces a very extensive field and a considerable amount of work has been carried to increase knowledge regarding these methods and to improve their application. It is generally recognised that most of the important methods of surface treatment of aluminium are dependent on electro-chemical processes and this useful book is primarily concerned with the electrolytic and chemical production of protective surface films. The object of the author is to throw light on the phenomena which occur in this comparatively limited field and to present a general survey of the present-day position in the field.

Since the introduction of chemical methods for the production of surface films on aluminium and its alloys many investigations have been undertaken with the object of intensifying the film of oxide, in order to augment the possibilities of application for this metal, and these led to the development of anodic oxidation which has become the main process recognised throughout the world. Protective films obtained by the anodic oxidation process are considerably thicker, harder and more absorbent than those produced by ordinary chemical processes; they are distinguished by high insulating properties and have opened the door for aluminium to the extensive field of electrical winding and coils; they are, furthermore, prominent by reason of their great resistance to weather conditions, their æsthetic appearance and their capacity for absorbing paints, water repelling greases and photo-chemical compounds.

The industrial applications of this anodic oxidation process made great progress, largely as the result of intensive research work and the subsequent development by aluminium producers and manufacturers of suitable plant for the process; to-day the quantity of aluminium treated by this process throughout the world must not be far short of 50,000 tons. Technically and commercially, anodic films rank in importance far ahead of the chemically produced protective films, and, with the rapid growth of the process, there is a special need for this book to facilitate its further application.

The original work, on which the present book is based formed one of a series of well-known *Technische Fortschrittsberichte* published by Theodor Steinkopff of Dresden and Leipzig. The author was Director of Research of the Siemens and Halske A-G. Electrochemical Laboratories, and a foremost authority on the subject of anodic oxidation, to the researches on which he has contributed notably, perhaps his best known work in this direction being his discovery and development of the use of oxide films on aluminium as a medium for permanent photography. The text of the original work has been supplemented by the translator with information gained from the Intelligence Department of the British Aluminium Co. Ltd.

The book is divided into two main parts, the first surveys the electrochemical processes which form the subject of discussion, and provides an outline of the chemical behaviour of metals towards gases, and of the anodic phenomena at metallic electrodes. This section concludes with a chapter on the chemical properties of aluminium and its alloys, and on the electrolytic behaviour and anodic oxidation of aluminium, sub-divided under direct current, alternating current, and combined current treatments. In the second section, the subject matter covers a general discussion on protective films, chemical phenomena at electrodes and in electrolytes, and the practical aspects of anodic treatment. An account is given of the commercial anodising processes, and a chapter is also included on the chemical processes available for the production of protective films on aluminium and its alloys, with particular reference to the MBV process.

This is the first authoritative book on the subject published in this country; it is written specially for those engaged in and controlling commercial anodising, and while it will have a special value, at the present time, for those engaged in aircraft and aircraft components, the increasing application of aluminium alloys in the more general engineering fields gives it a much wider interest and usefulness. We have no hesitation in recommending this book to all engaged on anodising processes, whether the connection is in practice or research.

By Dr. A. Jenny, translated by Winifred Lewis, B.Sc., published by Charles Griffin and Co. Ltd., 42, Drury Lane, London, W.C. 2, price 16s.

Strength of Materials

ORIGINALLY published in 1927 the demand for this book will be understood when it is appreciated that this is the fourth edition. It is primarily designed for engineering students working for the degrees of the University of London and the final examinations of the various professional institutions, but it will be found to cover the course of other universities, as well as being of considerable value to many practical engineers and designers.

The production of the present edition has provided an opportunity for a certain amount of revision and addition to the text. Several worked examples have been added in order to illustrate the use of certain formulae, and in some cases existing examples have been modified in order to present them in a clearer manner. New matter has been added dealing with riveted joints subjected to eccentric loading, and with the deflection of frameworks.

The book deals with simple and compound stresses and strains; simple mechanical properties of metals; thin cylinders, spheres and pipes; centre of gravity, moment of inertia, ellipse of inertia; bending moments and shearing forces; stresses in beams; slope and deflection; fixed and continuous beams, and beams with large original curvature; the torsion of shafts; columns and struts; thick cylinders and spheres; rotation of rings and discs, whirling of shafts; testing and testing machines; and creep of metals. Also included are several tables giving the elastic constants of many materials, the properties and uses of different steels, the tensile strength properties of copper alloys at elevated temperatures, a summary of formulae, and mathematical tables. The comprehensive nature of the work covered will be appreciated, while the examples and exercises at the end of each chapter taken from recent exmination papers of the University of London and the Institutions of Civil and Mechanical Engineers, greatly add to the value of the book.

By F. V. Warnock, M.Sc., Ph.D., published by Sir Isaac Pitman and Sons Ltd., Parker Street, Kingsway, London, W.C. 2; price 10s. 6d. net.

We have received a copy of the latest edition of a catalogue on standard power transmission appliances from Croft (Engineers) Ltd., Thornbury, Bradford. It is the seventh edition and has been enlarged to 540 pages. It is remarkably comprehensive and includes mechanical power transmission appliances, giving complete belt, rope, V-rope, chain and gear drives standardised to meet general industrial requirements. A considerable section is devoted to general engineering tables and will be found of great value to power users in all trades. Copies of this book can be obtained on application to Croft (Engineers) Ltd.

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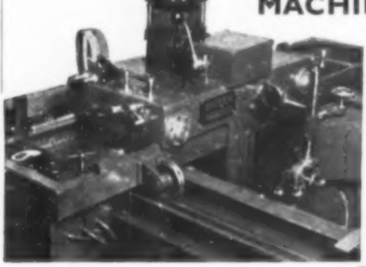

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